Bulletin 132

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary
BUREAU OF MINES
VAN. H. MANNING, Director

SILICEOUS DUST IN RELATION TO PULMONARY DISEASE AMONG MINERS IN THE JOPLIN DISTRICT, MISSOURI

BY

EDWIN HIGGINS, A. J. LANZA, F. B. LANEY
AND GEORGE S. RICE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

Bulletin 132

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

SILICEOUS DUST IN RELATION TO PULMONARY DISEASE AMONG MINERS IN THE JOPLIN DISTRICT, MISSOURI

BY

EDWIN HIGGINS, A. J. LANZA, F. B. LANEY
AND GEORGE S. RICE

Bulletin 132

DEPARTMENT OF THE INTERIOR

FRANKLIN K. LANE, SECRETARY

BUREAU OF MINES

VAN. H. MANNING, DIRECTOR

SILICEOUS DUST IN RELATION TO PULMONARY DISEASE AMONG MINERS IN THE JOPLIN DISTRICT, MISSOURI

BY

EDWIN HIGGINS, A. J. LANZA, F. B. LANEY
AND GEORGE S. RICE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines.* His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The price of this publication is 25 cents.

First edition. June, 1917.

CONTENTS.

TABLES.

ILLUSTRATIONS.

PREFACE.

Soon after the Federal mining investigations into safety and health conditions were begun, the late Dr. J. A. Holmes, who was in charge, had brought to his attention the serious conditions that prevailed among the metal miners of certain districts, seemingly from inhaling siliceous or flinty dust in their underground work and thereby contracting pulmonary diseases. With the assistance of the United States Public Health Service, Dr. S. C. Hotchkiss made a preliminary survey in Western mines. The result of the preliminary investigations indicated a widespread prevalence of pulmonary troubles among metal miners in certain districts.

Subsequently a special investigation was conducted in the Joplin district of Missouri in the so-called "hard-rock" or "sheet-ground" mines. Dr. A. J. Lanza, passed assistant surgeon of the United States Public Health Service, was detailed to the Bureau of Mines by the Surgeon General to cooperate with Edwin Higgins, mining engineer of the bureau, in conducting under the general supervision of George S. Rice, chief mining engineer, a careful investigation of the health of the miners and the effect of the mining conditions with especial reference to the prevalence of silicosis. The investigators enlisted the heartiest cooperation from the mine inspectors of Missouri and from the operators of the Joplin district. The miners themselves also proved anxious to assist in the inquiry. Accordingly, a large amount of valuable information was obtained, which is given in this publication. A preliminary report, published before the inquiry was finished, appeared in Bureau of Mines Technical Paper 105.

The effect of the investigation and of the cooperation with the inspectors, operators, and miners was remarkably good. Regulations were adopted by the State of Missouri, and the operators, many of them willingly, put into effect many improvements and introduced appliances to allay the dust and to lessen the exposure of the men to it. In consequence, it is believed that the serious conditions that still prevail in the district will be rapidly improved and that the health not only of the miners, but of the community, will be improved thereby.

The success of the Joplin inquiry has led me, in conjunction with the Surgeon General of the Public Health Service, to organize a

similar inquiry into the health conditions of the Butte copper mines of Montana, with special reference to the prevalence of silicosis, as preliminary reports indicate that this disease is prevalent in that district. It is hoped that, despite the more serious conditions due to the high temperatures in the deep workings, methods may be indicated by which the operators and miners may improve the health conditions, as has been done so successfully in the Joplin district.

VAN. H. MANNING.

SILICEOUS DUST IN RELATION TO PULMONARY DISEASE AMONG MINERS IN THE JOPLIN DISTRICT, MISSOURI.

By Edwin Higgins, A. J. Lanza, F. B. Laney, and George S. Rice.

MINING OPERATIONS AS RELATED TO PRODUCTION OF SILICEOUS DUST.

By Edwin Higgins.

INTRODUCTION

Under its organic act the Federal Bureau of Mines is directed to conduct investigations relating to the improvement of health conditions in the mineral industries. This report describes the lead and zinc deposits and the mining methods employed in the sheet-ground area of the Joplin district, Missouri, and discusses the causes and the methods of abating rock dust in the mines, the chemical and physical characteristics of the dust, and the quantities present in mine air. Although the preliminary investigation included a number of the "soft-ground" mines, the writer spent the larger part of his time in the sheet-ground mines, for in them alone was siliceous dust found in appreciable quantities. Some results of the preliminary investigation have been published by the Bureau of Mines in Technical Paper 105.[a]

The territory covered in the preliminary investigation, during the period between November 7 and December 6, 1914, embraced parts of Jasper, Lawrence, Newton, and Greene Counties, Mo., and outlying districts in Kansas and Oklahoma. The remainder of the field work, to which 84 days during the period from February 9 to July 19, 1915, were devoted, was confined to the sheet-ground mines, the most important of which are situated in the vicinity of Joplin, Webb City, Carterville, and other smaller near-by towns in Jasper County, Mo.

ACKNOWLEDGMENTS.

The writer is deeply indebted to the mine operators of the district for their uniform courtesy and cooperation, and to Messrs. C. M. Harlan, W. W. Holmes, and I. L. Burch, State mine inspectors, who did much to facilitate the field work. Thanks are extended also to various officials of the Bureau of Mines—to George S. Rice, chief mining engineer, for valuable suggestions regarding the conduct of the investigation; to G. A. Burrell, chemist, for assistance in perfecting

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines. 1915. 48 pp.

the rock-dust sampling device and for supervision of the analysis of air samples; to A. C. Fieldner, chemist, for directing the chemical and sizing tests and the weighing of the rock-dust samples; and to Reinhardt Thiessen, assistant chemist, for the microscopic work.

GENERAL INFORMATION.

In 1914, as shown in Table 1, the total number of employees in Greene, Jasper, Lawrence, and Newton Counties, Mo., was 5,369. This was a decrease of 982 as compared with 1913.

TABLE 1.—*Number of employees, wages paid, tonnage, and value of ores (concentrates) mined in the Joplin district during 1914.*[a]

County.	Number of miners employed.	Average daily wage.	Number of other employees.	Average daily wage.	Total number of employees.	Zinc (blende).	
						Amount mined, tons.	Value.
Greene	14	$2.00	7	$2.50	....	800	$30,500
Jasper	3,460	2.69	353	2.66	4,956	136,646	5,370,880
Lawrence	29	2.00	20	2.25	49	146	2,780
Newton	234	2.38	127	2.50	364	7,731	216,367
Total	3,737	....	507	....	5,369	145,323	5,620,527

County.	Zinc silicate (calamine).		Lead (galena).		Dry bone (smithsonite).		Total value of all minerals mined.
	Amount mined, tons.	Value.	Amount mined, tons.	Value.	Amount mined, tons.	Value.	
Greene	....	....	160	$5,646	....	....	$36,146
Jasper	1,503	$25,255	18,718	927,229	330	$14,024	6,337,388
Lawrence	7,868	27,291	6	240	261	8,101	38,412
Newton	11,595	268,902	1,474	64,923	81	2,236	522,858
Total	20,966	321,448	20,358	998,038	672	24,361	6,934,804

[a] Taken from the Twenty-eighth Annual Report of the Bureau of Mines, Mining, and Mine Inspection, of the State of Missouri.

Because of an unprecedented demandfor zinc ore in the first half of 1915, occasioned by the war in Europe, the number of men employed in and about the mines probably increased 30 per cent, many abandoned mines were reopened, and new development work was started. In short, the mining throughout the district became more active than ever before.

Table 2, which gives the number and location of the active mines in the State of Missouri on May 1, 1915, shows that the number of sheet-ground mines in operation had increased to 55 and the number of employees to 926 on the surface and 2,744 under ground. The total number of employees in all types of mines increased to 6,914; this total does not take into account an unknown number of prospectors and "gougers."

TABLE 2.—*Location and number of employees of active mines in southwestern Missouri in May, 1915.*

Location.		Number of active operations, sheet ground.	Number of employees, sheet ground.		Number of active operations, disseminated and others.	Number of employees, disseminated and other mines.	
Town.	County.		Surface.	Underground.		Surface.	Underground.
Joplin	Jasper	11	132	390	40	425	740
Webb City	do	16	237	705	7	50	110
Carterville	do	6	170	606	15	85	150
Duenweg	do	4	71	217	20	115	180
Neck City	do				9	112	230
Oronogo	do	2	48	140			
Prosperity	do	10	152	334	8	25	40
Carthage	do				5	40	75
Carl Junction	do	1	20	35	2	10	20
Alba	do				4	38	66
Porto Rico	do	5	96	317	2	15	20
Sarcoxie	do				1	9	15
Spring City	Newton				6	86	177
Granby	do				8	61	127
Melva	Taney				1	10	20
Springfield	Greene				3	23	45
Aurora	Lawrence				6	40	85
Total		55	926	2,744	137	1,144	2,100
Total for November, 1914[a]		51	774	2,475	118	1,063	1,986

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines; a preliminary report: Tech. Paper 105, Bureau of Mines, 1915, p. 14.

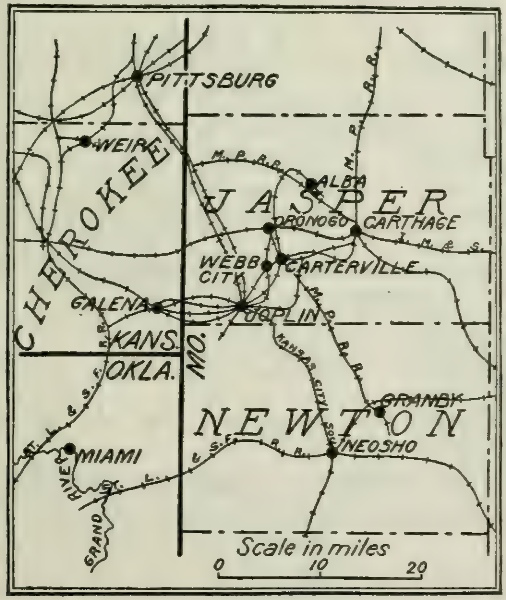


FIGURE 1.—Sketch map of southwestern Missouri and parts of Kansas and Oklahoma, showing *area of active mining* in sheet-ground district.

Several counties in southwestern Missouri and closely adjoining parts of Kansas and Oklahoma are shown in figure 1. Figure 2 shows the territory from Oronogo, Jasper County, Mo., southeasterly

through Webb City, Carterville, Prosperity, Porto Rico, and Duenweg, wherein are situated a large proportion of the sheet-ground mines.

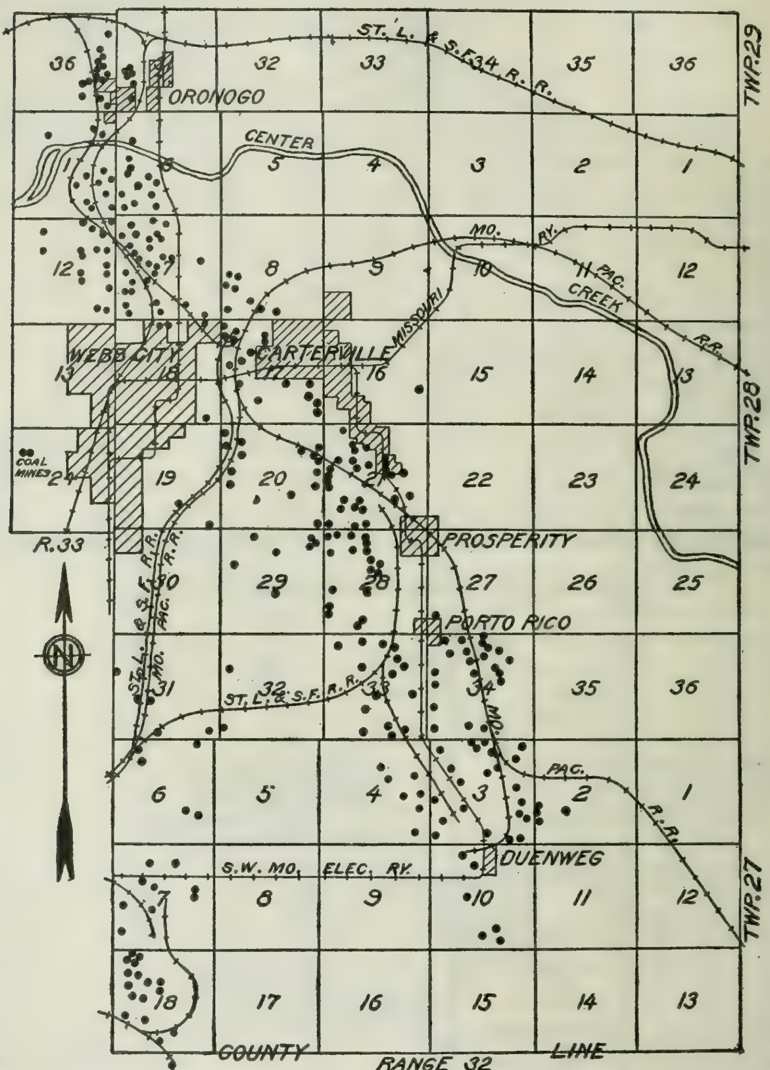


FIGURE 2.—Map of Webb City-Carterville mining district, in which is situated a large proportion of the sheet-ground mines.

The area and extent of the sheet-ground district has been described by Siebenthal[a] in his report on the Joplin district.

[a] Siebenthal, C. E., Joplin district, Missouri, U. S. Geol. Survey Folio 148, 1907.

GEOLOGY AND ORE DEPOSITS.

Details of the geology of the Joplin district may be found in various publications,[a] and have been briefly discussed in Technical Papers 41 [b] and 105.[c] The following statements are general, but bring out some of the more important features.

The ore deposits may be divided broadly into two classes: (*a*) Those termed "sheet-ground deposits" (in chert), and (*b*) those in which the ore lies in "runs" or irregular pockets (in limestone). As regards prevalence of siliceous dust, the latter deposits need not be seriously considered. In Jasper County, where are the greater number of sheet-ground mines, the ore deposits occur chiefly in the Grand Falls member of the Boone chert, a formation in the Mississippian series of the Carboniferous system. The sheet-ground deposits consist of bedded chert in layers a few inches to 30 inches thick, which lie almost horizontally. The chert beds range from 6 to 30 and sometimes 45 feet in thickness.

The "runs" or irregular bodies of ore occur in both hard and soft ground. As a rule they lie at shallower depths than the sheet-ground deposits, but in places they lie directly below the chert, and although the ore is closely associated with chert the ground may, or may not, consist largely of limestone in the form of bowlders or masses.

The following description [d] of the rock composing the sheet ground is of interest as bearing on the nature of the dust produced:

> The typical Grand Falls chert of the Boone formation is of the splintery, fresh, unaltered appearing type known as "live" or "butcher-knife" flint. Much of it has been thoroughly crushed in place and recemented with a darker bluish siliceous cement, the original bed remaining practically undisturbed. Where the chert has been subjected to rather sharp deformation instead of suffering simple brecciation, it loses its bedded character and becomes gnarled and knotted in structure, weathering with a very rough surface.

---

[a] Schmidt, A., and Leonard, A., Lead and zinc regions of southwestern Missouri: Missouri Geol. Survey, vol. 1, 1874, pp. 381–502; Winslow, A., Lead and zinc deposits: Missouri Geol. Survey, vols. 6, 7, 1894; Jenney, W. P., Lead and zinc deposits of the Mississippi Valley: Trans. Am. Inst. Min. Eng., vol. 22, 1894, pp. 171–225, 642–646; Bain, H. F., Van Hise, C. R., and Adams, G. I., Preliminary report on the lead and zinc deposits of the Ozark region: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 23–228; Smith, W. S. T., Lead and zinc deposits of the Joplin district, Missouri-Kansas: U. S. Geol. Survey Bull. 213, 1903, pp. 197–204; Buckley, E. R., and Buehler, H. A., Geology of the Granby area: Missouri Bureau Geology and Mines, 2d ser., vol. 4, 1906, p. 57; Haworth, Erasmus; Crane, W. R.; Rogers, A. F.; and others, Special report on lead and zinc: Univ. Geol. Survey Kansas, vol. 7, 1904, pp. 20, 45, 48, 484.

[b] Wright, C. A., Mining and treatment of lead and zinc ore in the Joplin district, Missouri, a preliminary report: Tech. Paper 41, Bureau of Mines, 1913, pp. 9–11.

[c] Lanza, A.J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines: Tech. Paper 105, Bureau of Mines, 1915, pp. 15–16.

[d] Siebenthal, C. E., Joplin district, Missouri, U. S. Geol. Survey Folio 148, 1907.

The following record of a drill hole near Carterville, Mo., in the heart of the sheet-ground area, shows 45 feet of sheet ground:

Record of drill hole near Carterville, Mo.

	Feet.
Soil	2
Yellow clay	18
Gravel	10
Yellow clay	10
Soapstone	64
Chert and dolomitic limestone, in alternate layers	116
True sheet ground	45
Dolomitic limestone	25
	290

The sheet ground varies in depth below surface, in thickness, and in the number of beds that may be encountered. In the principal area, in the vicinity of Joplin and the towns between Oronogo and Duenweg, it may lie anywhere from 140 to 240 feet below the surface, and may be divided into two or more beds, with limestone between. In other parts of the district, however, because of differences in the dip of the strata and erosion, the sheet ground is encountered at depths of less than 100 feet.

Sphalerite, or zinc sulphide, locally termed "jack," and galena, or lead sulphide, termed "lead," are the valuable minerals of the ore bodies. These minerals are usually closely associated, but in widely varying proportions, in well-defined bands a fraction of an inch to 6 inches thick, which lie between the bedding planes of the flint at varying intervals. An ore body may consist only of one band of mineral, or it may be made up of two or more bands at varying distances apart.

PROSPECTING AND DEVELOPMENT WORK.

As the surface is comparatively level, and soil, clay, sand, and bowlders extend to varying depths, rock outcrops are seldom seen. Churn drilling has been found to be the most satisfactory method of prospecting. Although such drilling is well adapted to the flat-lying ore deposits, the results obtained may be misleading unless enough holes are drilled. As a rule the ore deposits are not pockety, but a single drill hole may pass through an ore body at a point where it is richer, or much leaner, than the average.

Keystone and Star churn drills are chiefly in use. Usually a hole is started with 6-inch and finished with 4-inch casing. Rarely is drilling continued below the sheet ground, so that there are few drill holes in the sheet-ground district deeper than 250 feet. Drilling costs from 90 cents to $1 per foot. The average time required to drill a 200-foot hole is about two weeks.

After the location of the ore body by drilling, a shaft, measuring usually 4 by 5 to 5 by 7 feet inside the timbers, is sunk. In sinking shafts, corner, side, and sump holes are drilled; only one set of sump holes is required in soft ground. Shafts are timbered as far down as the limestone with 2 by 4 inch rough lumber placed crib fashion, without special framing, on the four sides of the shaft, the space between the 2 by 4 inch timbers being filled with short pieces of the same material. Practically no blocking is used, but the cribbing is strengthened by 2 by 4 inch lumber, one or two strips of which are nailed against each side of or in the corners of the shaft, and extend from the collar to the bottom of the timbering. No ladders are used in the shafts. Men are raised and lowered in buckets and supplies and machinery either in the bucket or with the cable. No guides or crossheads are used, buckets being allowed to swing freely in their passage through the shaft. Water columns, air lines, and electric-power lines, when used, are usually placed in a corner of the shaft. Plate I, *A*, shows a prospector operating a horse whim by hand.

At the bottom, a station is cut, pillars are left to protect the shaft, and mining is begun. As a rule, development follows the ore, and a mine may be developed in one or more directions from the shaft; however, it is usually possible to work in all directions. This permits almost any arrangement, as far as trackage and layout of station are concerned, that may be desired. The "ground" (rock) is drilled and blasted down and the resulting "dirt" (broken rock) is shoveled into "cans" (buckets). The cans are trammed singly by hand, or in trips by power or mules, to the shaft station, where they are hooked onto the cable, hoisted to the top of the "derrick" (headframe), and dumped onto a 5 or 6 inch grizzly. The dirt then starts on its way through the mill. With a few slight modifications, this may be said to be the method followed in all the sheet-ground mines.

The surface works of a mine near Carterville are shown in Plates II and III.

MINING METHODS.

The winning of ore in the mines presents no great problem, only the excavation and removal of varying thicknesses of cherty flint from comparatively shallow depths. Probably the greatest difficulties encountered are in drilling and blasting the tough flint, much of which contains fissures. Experience has shown that it is much cheaper to mine from many shafts simply equipped, rather than to utilize fewer shafts of more elaborate equipment. Probably 300 feet is a fair average for the distance between shafts. The workings of a typical sheet-ground mine present the appearance of a large horizontal chamber, the roof being supported by pillars that differ in size and spacing according to the nature of the rock and the height

of the roof. The height of the workings, of course, depends on the thickness of the pay dirt; the lateral dimensions on the extent of the ore body. A plan of the workings of a typical mine is shown in figure 3.

The methods of mining used can be divided into what may be termed heading work, in which the rock is broken from floor to roof with a single round of holes; and mining by stope (bench) and heading, the heading being carried above and in advance of the stope. Without reference to the method of breaking the ground, the term "longwall advancing" is applicable to the manner of carrying the face.

BREAKING GROUND IN THE HEADING.

Deposits of from 7 to 18 feet in height are usually broken with a single round of shots, the face being carried vertically. Although the stope and heading method is used in some of the mines, where

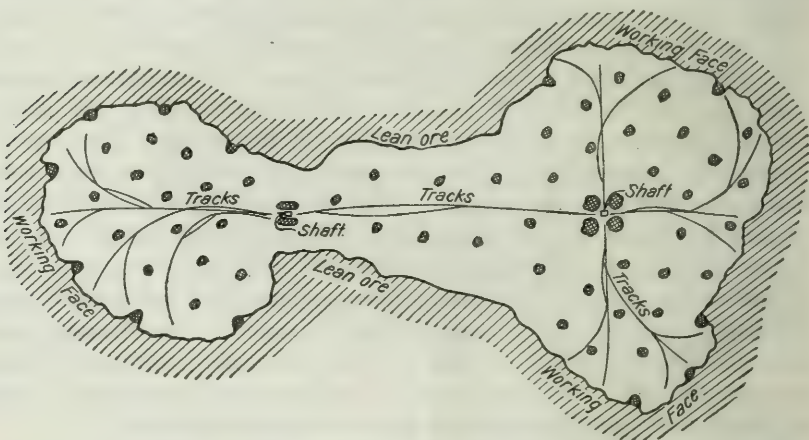
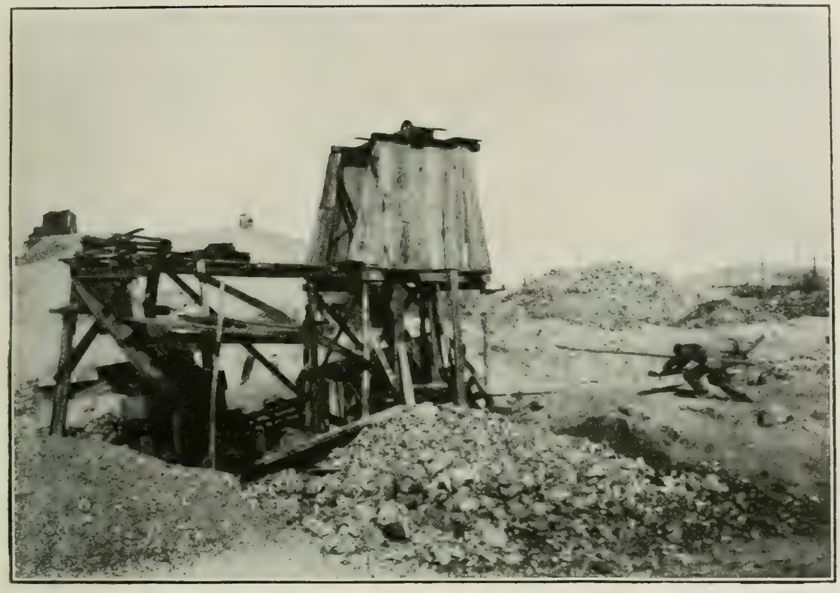


FIGURE 3.—Plan of workings in a typical sheet-ground mine.

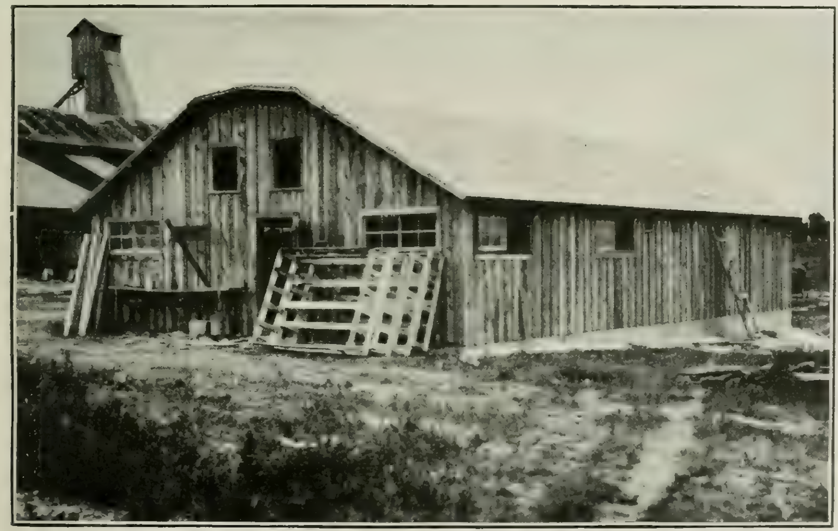
the deposit is 15 to 18 feet thick (see A, fig. 4), the tendency in recent years has been to carry only a heading. The method of carrying the face and placing drill holes in heading work, the system most commonly employed, is shown in figure 5. The plan of the working face (A, fig. 5) is irregular in outline, as obviously the ground breaks more easily when an irregular face is carried.

The condition and shape of the face are the main factors in determining the number and location of drill holes; three to six holes constitute a round. Three common methods of placing holes are shown in figure 6. The numbers indicate the order in which the holes are fired. The upper holes are called roof holes; those midway between the roof and floor, breast holes; and those near the floor, stope holes.

In the 6-hole round, No. *1* is termed the relief hole; *2*, the front breast; *3*, the front stope; *4*, the back roof; *5*, the back breast; and *6*,



A. PROSPECTOR NEAR CARTERVILLE, MO., OPERATING HORSE WHIM BY HAND.



B. NEARLY COMPLETED DRY-AND-CHANGE HOUSE NEAR DUENWEG, MO.

the back stope hole. The holes are drilled approximately parallel to what might be termed a subface, and are 6 to 15 feet long, corresponding in length roughly to the height of the roof. The dotted lines at the points *a* and *b* (A, fig. 5) indicate the ground that will be broken by the rounds of shots at those places.

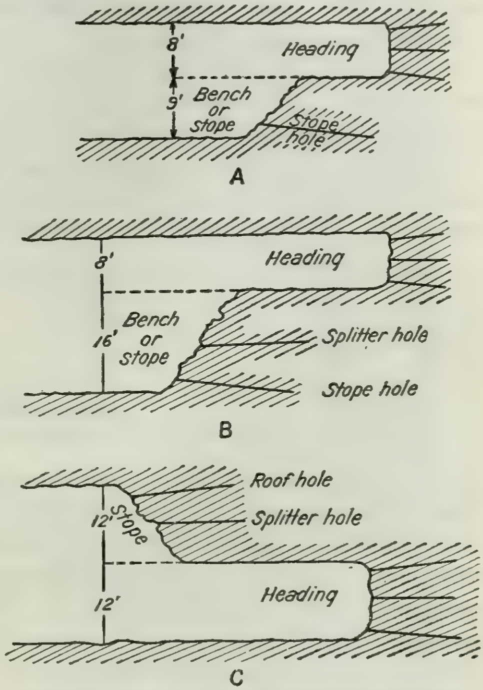


FIGURE 4.—Methods of breaking ground in thick deposits.

CARRYING STOPE AND HEADING.

Deposits 15 to 30 feet or more in thickness are usually mined with a stope (bench) and heading. The methods used in one of the larger mines are typical of the practice in the entire district. At this property the mineralized ground is 24 feet thick. The usual method of breaking the ground is shown in figure 4 (B). The chert is uniformly hard, with the exception of a small band of what is called "cotton rock" in the floor of the heading. The roof, which consists of 3 to 4 feet of chert, is considered good; limestone lies above the chert.

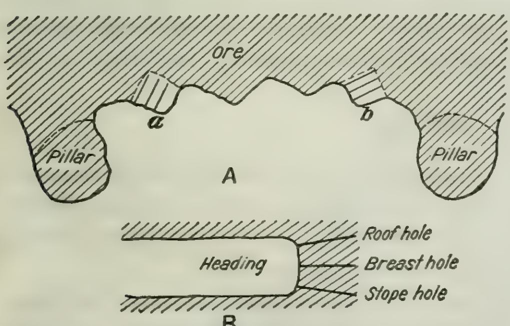


FIGURE 5.—Methods of breaking ground in deposits of medium thickness.

The heading is carried 8 feet high and 15 to 20 feet in advance of the stope, the drill holes being 7 to 8 feet long. The bench or stope is 16 feet thick, and is broken with stope and "splitter" holes 18 feet in length. The splitter hole is pointed slightly upward; the stope hole slightly downward. These holes are chambered three or four times with charges ranging from 4 or 5 sticks of dynamite for the first charge to about 30 sticks for the last one. When ready for blasting each hole will contain from 3 to 4 boxes (150 to 200 pounds) of dynamite. With such charges, two stope and two

splitter holes will break the 16-foot bench across a width of 10 to 12 feet. In this mine an 18-foot hole has been drilled in 1½ hours, but holes of this depth where the chert contained many fissures have required as much as 8 hours.

In another part of this mine a practice was noted that is not usual in the district. The chert at that place is also 24 feet thick, but the upper 12 feet of the deposit is extremely tough. The heading is carried in the soft ground below, and the stope or bench above, each 12 feet high, as shown in figure 4 (C). The heading is carried in the usual way, the drill holes being 12 feet in length. The upper part, in

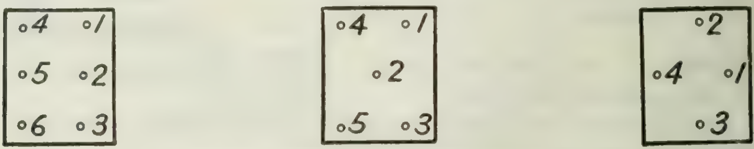


FIGURE 6.—Three methods of placing drill holes.

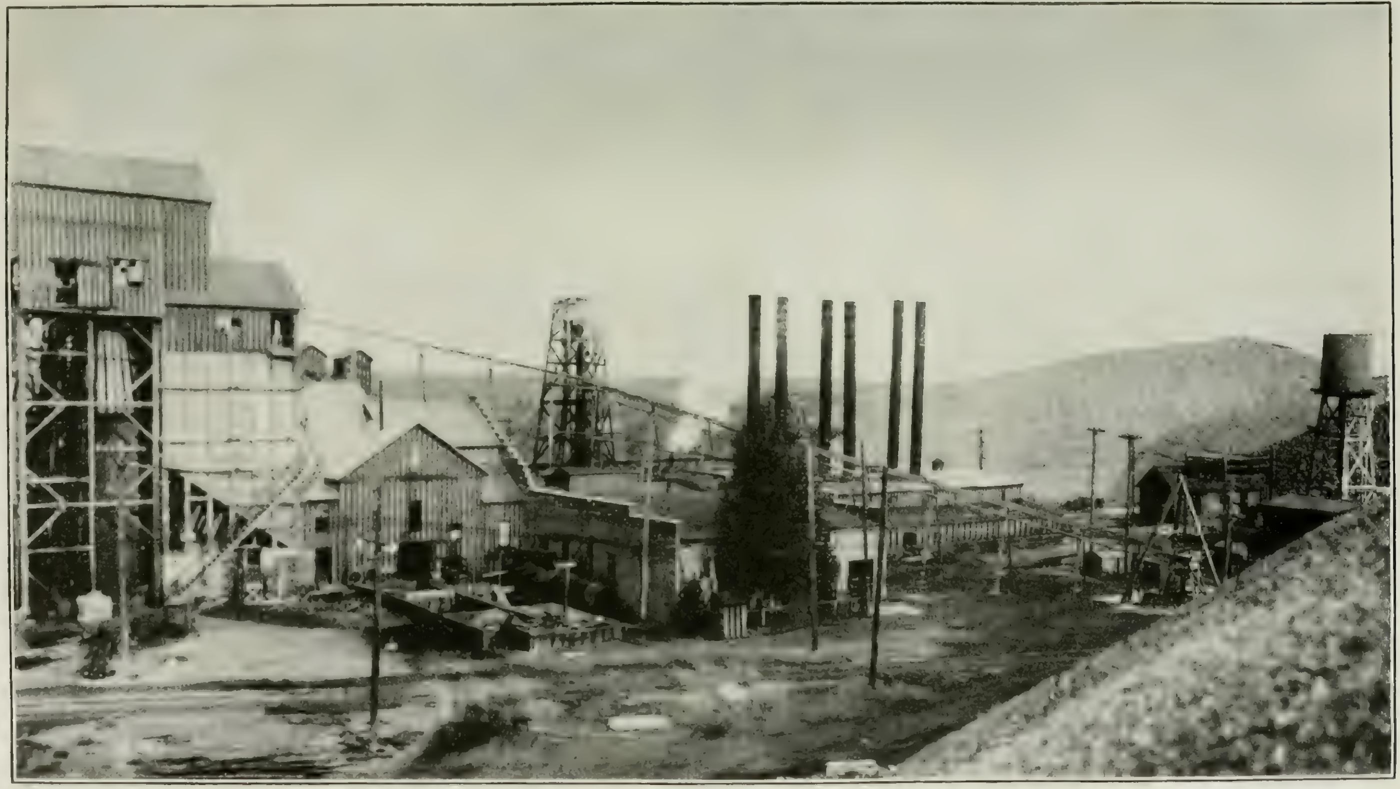
this case the stope, is broken with roof and splitter holes 12 to 14 feet long. The splitter holes are chambered, but the roof holes are left as drilled for fear of loosening the roof. This stope is carried from 50 to 100 feet back of the heading. This method of mining is much less costly than the first one described. Five machines here produce an average of 650 (1,000-pound) buckets of dirt in 8 hours. This amount of dirt is loaded by 11 shovelers.

In some places, after a certain thickness of ground has been worked, further prospecting shows pay dirt in the floor. To mine this lower stratum all that is necessary, after cutting out the floor at the shaft station, is to drill and blast long stope holes or lifters. This procedure is called "taking up stope," and is a very cheap method of mining. One machine will produce as much dirt as eight machines in the heading; also, the cost of explosives is much less than in the heading.

DRILLING.

All drilling is done with machine drills operated at air pressures of 60 to 90 pounds at the machine. A large proportion of the drills are of the solid-steel piston type; also successful experiments have recently been made with water-injection hammer drills.

For heading work the machine is mounted on a column; for stope work a tripod is used. A compilation of drilling records from practically all of the sheet-ground mines shows that one machine will drill 20 to 35 feet per shift and produce 35 to 45 tons of dirt, depending on the nature of the ground.



VIEW OF PLANT NEAR CARTERVILLE, SHOWING MILL BUILDINGS AND TAILING HEAPS.

ANOTHER VIEW OF PLANT SHOWN IN PLATE II, SHOWING OFFICES AND TAILING HEAPS.

SQUIBBING, BLOWING HOLES, BLASTING.

"Shelly" ground and fissured ground cause the drill steel to stick. The drill helper usually tries to prevent this sticking by repeatedly striking the drill steel with some heavy tool. If this fails to make it work freely, the general practice is to remove the drill and fire a stick or two of dynamite in the hole. This practice, called "squibbing," is one of the chief causes of siliceous dust in the mines. Although squibbing is an effective method of cleaning holes, it is usually unnecessary, because in most cases the sticking of the drill steel may be remedied by properly aligning the machine. Also, squibbing is expensive because it uses up explosive and causes the drill crew, together with the shovelers and other drill crews near by, to lose 3 to 10 minutes' time, for these men must all leave their working places and seek safety behind a pillar when the squib is fired.

Owing to the toughness of the chert, the drill holes must be chambered in order that sufficient dynamite may be introduced into the hole to break the ground. The chambering of holes is also referred to as squibbing.

Practice varies in the different mines, but it has been found most satisfactory to drill a round of holes, squib or chamber them when the men leave the mine, and shoot them at the end of the following shift, so that a round of holes is drilled one shift before blasting. If squibbing or blasting is done while men are underground, they are exposed to an atmosphere containing noxious gases from the blasts and large quantities of siliceous dust.

At various intervals, but chiefly before squibbing or blasting, it is necessary to remove the cuttings from the drill hole. A pipe attached to the compressed-air line is inserted in the drill hole, the air turned on, and the pipe worked backward and forward until all the cuttings have been blown out. This practice effectively cleans the hole, but unless it has been thoroughly wet the workings in the vicinity will be filled with a dense cloud of dust.

Ammonia and gelatin dynamites of 33 to 40 per cent strength are used in most of the mines, the ammonia dynamite for dry and the gelatin for wet holes. In exceptional cases stronger dynamites are used in long stope holes. In some of the mines "80 per cent" gelatin dynamite is used for squibbing.

In mining sheet ground the explosives constitute one of the chief items of expense, varying from 20 to as much as 30 per cent of the total cost. A box of 50 pounds of dynamite will break from 30 to 45 tons of dirt, according to the nature of the ground and the kind of face carried.

PILLARS.

The chief factors to be considered in determining the size and frequency of pillars are the nature of the ground, the thickness of the deposit, and the character of the roof. No set rule governs the practice, pillars being left as conditions may require. In some of the mines the roof is very good, but in others the cherty flint tends to fall readily; usually when the roof falls it comes down in slabs 3 to 30 inches thick. In some of the old workings of the sheet-ground mines pillars 100 feet or more apart may be seen. In some of these places the roof has fallen over a large area in sheets 1 to 2 feet thick.

The tendency in recent years has been to leave pillars 40 to 60 feet apart, arranged in "five-spot" form. This arrangement supports a slabby roof better and is superior to the method used in former years of placing pillars in well-defined rows. Some idea of the arrangement of pillars may be obtained from figure 3, which also shows pillars in the making. Ten to thirty per cent of the ground is left for pillars. In some of the mines leasers are allowed to clean up floors and pillars after company work has ceased. The leasers usually cut the pillars down to a width that allows little or no factor of safety. Some serious caves have resulted from this practice, and were it not for the vigilance of the mine inspectors caves would be more frequent.

In leaving shaft pillars sufficient attention is not always given to convenience of future operation. In some of the mines where the ground around the shaft station was very rich, rock has been removed that should have been left. In exceptional cases shafts have been left almost entirely unprotected. Figure 3 shows two different arrangements of shaft pillars. The shaft on the left is protected by two oblong pillars. In deposits of medium thickness, the shaft pillars would be about 20 feet wide and 30 feet long; in thicker deposits they would be larger. The shaft shown on the right is protected by four circular pillars, a desirable arrangement as it permits haulage in any direction. Pillars so arranged would range from about 20 feet in diameter for deposits of medium thickness to 30 feet for thicker deposits.

SHOVELING, TRAMMING, AND HOISTING.

The broken ore, or dirt, is shoveled into buckets holding 1,000 to 1,650 pounds and trammed on small trucks to a switch, called the lay-by, near the face. From the lay-by the trucks are usually hauled to the shaft by mules or power, but frequently the shoveler trams the bucket to the shaft.

Most of the ore breaks in pieces small enough for shoveling, but there are many large bowlders. Bowlders that can not be broken with a sledge are blasted. This practice is known as "bowlder popping."

The shovelers, or "cokeys," as they are called, are paid by the bucket, and load 30 to 70 or 80 buckets in an 8-hour shift. There are some records of one man loading 90 and even 100 buckets and more per shift. The average day's work for a shoveler in all the sheet-ground mines is 22 tons per 8 hours.

The track gage ranges from 12 to 24 inches, 8 to 12 pound rails being used. There are two methods of spotting the loaded truck at the shaft station. The truck carrying the bucket may be stopped under the exact center of the shaft, so that it is not necessary to balance or steady the bucket after it leaves the truck. The descending empty bucket, however, must be drawn to one side before it is landed. The other method is to place the truck for the empty bucket in the center and stop the loaded bucket to one side of it. In this method it is necessary to center the loaded bucket after it leaves the truck.

The "derricks" or headframes range from 40 to 70 feet in height, depending on the elevation at which the dirt must be delivered to the mill.

Geared hoists, operated either by steam or electricity, are commonly used. There are some first-motion steam hoists. The hoist is installed near the top of the "derrick" in such a position that the hoist engineer from his seat at the throttle or controller has an unobstructed view to the bottom of the shaft. The hoisting rope is usually one-half to five-eighths of an inch in diameter and of steel. When a truck with a loaded bucket reaches the shaft station, the "tub hooker" or station tender attaches the cable hook to the bail of the bucket, which is then hoisted to the top of the derrick, drawn to one side by means of a hook attached by the engineer to a ring in the bottom, and quickly dumped, the ore falling on an inclined grizzly with bars spaced 5 to 6 inches. The bucket, without having been removed from the cable, is immediately returned to the shaft and lowered to the bottom, where it is immediately detached from the cable and a loaded bucket made fast.

In hoisting dirt an efficient hoist man and tub hooker work together with practically no loss of time. Dirt is hoisted without signals, the engineer apparently knowing just how much time to allow for the changing of the cable hook from the empty to the loaded bucket. It is common practice to raise and dump 120 buckets or more in one hour.

The fact that the engineer, from his place at the throttle or lever, has an unobstructed view of the bucket as it passes through the shaft makes for safety. Should the bucket, loaded either with dirt or men, approach the sides of the shaft too closely, the engine may be stopped or the speed lessened. In some of the mines there is in the shaft station an alarm gong, which may be sounded by a push button convenient to the engineer. In case a bucket of dirt is overturned in the shaft he is thus enabled to warn the tub hooker and any others who may be in danger at the shaft station.

MINE WATER.

Records of the various mines examined show that quantities of water are pumped ranging from a few gallons up to as high as 1,500 gallons per minute. In some places one pumping plant handles the water from several mines. The amount of water made by a mine, however, is no indication of the amount of siliceous dust that may be produced, for the working faces may be higher than the principal source of water, and therefore may be dry. Mines making as much as 1,000 gallons of water per minute were found to have dusty working faces, whereas mines producing much smaller amounts showed relatively less dust at the faces.

VENTILATION.

Most of the sheet-ground mines are well ventilated, after development, by natural air currents, as most mines have two or more shafts. In the vicinity of Webb City and Carterville the sheet-ground mines under a large area are connected, and it is possible to walk several miles underground through various properties without returning to the surface.

In such mines or in mines having more than one opening, although the air circulation between shafts is usually excellent, at the working faces, especially as they get farther away from a shaft, the air circulation may be poor. However, as indicated by the analyses of the air samples given in Table 3, the quality of the air at the faces seems to be affected but little. This is probably due to the usually great size and extent of the mine workings. With the relatively large volume of air, vitiation by the breathing of men, burning of lights, and combustion of explosives is evidently almost negligible. Also these mines use practically no timber in the workings, so that the absorption of oxygen and the production of carbon dioxide by decaying timbers is a factor that need not be considered. Pure atmospheric air contains approximately 20.93 per cent oxygen, 79.04 per cent nitrogen, and 0.03 per cent carbon dioxide. Table 3 shows that all the mine air sampled was nearly normal.

TABLE 3.—*Description and analyses of air samples taken in mines of Joplin district, November, 1914.*

Laboratory No.	Name of mine.	Place in mine where sample was taken.	Date taken (1914).	Analysis. CO$_2$.	O$_2$.	CO.	N.	Remarks.
				P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	
5637	Schoolhouse	Heading 13	Nov. 16	0.26	20.79	0	78.95	Taken 2 minutes after squibbing 9-foot hole with 2 sticks of 35 per cent gelatin dynamite.
5638	do	do	do	.11	20.85	0	79.04	Duplicate of No. 5637.
5639	Little Princess	West slope, No. 2 mill shaft.	Nov. 17	.21	20.74	0	79.05	Taken after squibbing 14-foot hole with 15 sticks of 35 per cent ammonia dynamite.
5640	do	do	do	.16	20.79	0	79.05	Duplicate of No. 5639.
5641	Ice Plant	Heading 7	do	.11	20.83	0	79.06	Taken after squibbing hole with 2 sticks of 27 per cent ammonia dynamite.
5642	do	do	do	.08	20.88	0	79.04	Duplicate of No. 5641.
5635	Longacre & Chapman.	Bottom of main shaft	Nov. 16	.07	20.92	0	79.01	Main return air.
5636	do	do	do	.07	20.92	0	79.01	Duplicate of No. 5635.
5630	Davey No. 3	Drift south of No. 7 shaft.	Nov. 9	.07	20.91	0	79.02	Main return air.
5629	do	do	do	.07	20.92	0	79.01	Duplicate of No. 5630.
5627	do	Face of No. 10 drift	do	.10	20.81	0	79.09	
5628	do	do	do	.07	20.90	0	79.03	Duplicate of No. 5627.
5631	Coahuilla	Station at main shaft	Nov. 10	.07	20.84	0	79.09	Main return air.
5632	do	do	do	.10	20.84	0	79.06	Duplicate of No. 5631.
5626	Electrical	Southeast heading	Nov. 19	.11	20.86	0	79.03	Taken one-half hour after squibbing 2 holes with 36 sticks of 80 per cent gelatin dynamite.
5625	do	do	do	.07	20.86	0	79.07	Duplicate of No. 5626.
5623	Oronogo Circle	South heading	Nov. 18	.11	20.88	0	79.01	Taken after squibbing 11-foot hole with 3 sticks of 35 per cent gelatin dynamite.
5624	do	do	do	.10	20.85	0	79.05	Duplicate of No. 5623.
5622	Florine	do	do	.10	20.81	0	79.09	Taken after squibbing hole with 2 sticks of 35 per cent ammonia dynamite.
5621	do	do	do	.21	20.69	0	79.10	Duplicate of No. 5622.
5633	Wilson	Heading 300 feet east of main shaft.	Nov. 11	.14	20.75	0	79.11	Taken after squibbing hole with 3 sticks of 33 per cent gelatin dynamite.
5634	do	do	do	.11	20.93	0	78.96	Duplicate of No. 5633.
5680	Hornbrook	Second south face	Nov. 25	.07	20.78	0	79.15	Taken 5 minutes after shooting two 7-foot holes with twenty $\frac{7}{8}$-inch sticks of 40 per cent gelatin dynamite.
5679	do	do	do	.11	20.74	0	79.15	Duplicate of No. 5680.

TEMPERATURES.

The temperature in the working places of the mines ranges from 52° to 65° F., the corresponding relative humidity being 82 to 100 per cent. The surface temperature ranges from 30° to 60° F., the relative humidity averaging 50 per cent, during October, March, and April, and up to 80° and 95° F. in July. The surface temperature apparently has little or no effect on the underground temperature, despite the shallowness of the mines. Although the humidity was high in most of the working places visited by the writer, this condition caused no great inconvenience, owing to the relatively low temperature.

WAGES AND COSTS.

During the three years previous to 1915, drillmen received $2.25 to $3 for an 8-hour day, drill helpers $2 to $2.50, and shovelers 6 to 9 cents per bucket. During this period the zinc concentrate produced was sold at an average of about $43 per ton, and the lead (galena) concentrate at $52 per ton. The cost of mining and milling ranged from 80 cents to $1.25 per ton of dirt handled, a fair average for the larger operations being $1 per ton. The cost, then, of mining and milling 100 tons of dirt under such conditions would be $100. If this were "2 per cent" dirt,[a] carrying only zinc, it would yield 2 tons of concentrate, which, at $43 per ton, would return $86. Thus it may be seen that unless costs are kept below the average, it is not possible to make a profit on 2 per cent dirt with low prices for ore.

During the first quarter of 1915, owing to the great demand for spelter, occasioned by the European war, the price of zinc concentrate began to rise. Sales were recorded during the first half of 1915 as high as $135 per ton. At the same time the cost of labor increased. Drillmen received from $3.50 to $4.50, drill helpers $2.75 to $3.75, and shovelers as high as 15 cents per bucket.

During 1912, 1913, and 1914 the costs of mining were distributed as follows by one large company:

	Cents per ton.
Ground boss	1.0
Drilling	18.5
Blasting	16.0
Roof protection	.7
Shoveling	15.0
Mule haulage	6.0
Track work	2.3
Hoisting	4.0
Lighting	.6
Sundry	1.0
Total mining cost	65.1

[a] In the Joplin district, "2 per cent" dirt means dirt that yields 2 tons of concentrate for each 100 tons mined, without allowing for the usual 25 to 30 per cent loss in concentrating.

The cost of milling averaged 27 cents per ton, making the total cost of mining and milling 92.1 cents.

The summarized mining costs of another large company for the six-year period 1909 to 1914 were as follows:

	Cents per ton.
Labor	33
Explosives	10
Air	4
Other expenses	8
Total	55

At this plant the cost of milling averaged 30 cents, and the cost of mining and milling, including everything except depreciation, was 98 cents per ton.

The costs of mining and milling by another large company for the year 1914 were distributed as follows:

	Cents per ton.
Labor	49.15
Explosives	20.49
Fuse	.57
Gas and electricity	14.28
Superintendence and repairs	12.12
Other expenses	3.39
Total mining and milling	100.00

The above figures, of course, should not be used in connection with the high prices of ore existing in 1915. With the increase in wages, the cost of mining and milling increased to $1.50 up to $2 per ton, and even more at some properties.

COMMENTS ON THE METHODS EMPLOYED.

To one not familiar with conditions in the Joplin district, the mining and milling methods may seem crude and inefficient, but the methods used are actually about as efficient as those in use in any metal-mining district in the United States. In the sheet-ground mines the working faces are, in two or three years' mining, extended to points far distant from the shaft, making necessary the sinking of new shafts from time to time. Obviously, elaborate shaft equipment, with ore pockets and skips, would be an extravagance. As a matter of fact, expensive mine equipment does not pay in this district, and it would be difficult to improve greatly on the methods in use, as far as costs are concerned. There are few metal-mining districts in the United States where ore can be mined and milled for $1 and less per ton, or where the output averages 10 tons per man employed underground, as is the case in the sheet-ground mines of the Joplin district.

ORIGIN OF SILICEOUS DUST IN MINE AIR.

Siliceous dust is present in varying quantities in the air of all operating sheet-ground mines, the quantity made and kept in suspension depending largely on the methods employed. Mines that are well ventilated and those that have wet working places are usually not dusty; however, they may be very dusty unless care be observed in certain details.

The causes of the production of siliceous dust, and its suspension in the mine air, are drilling, squibbing, blowing cuttings out of drill holes with an air blast, blasting, shoveling, bowlder popping, tramming, and roof and pillar trimming. The blowing of dry drill holes, squibbing, and bowlder popping are the chief practices that raise the dust into the mine air. On the surface dust is made by the dumping of the bucket and the crushing of rock in the mill.

The method of mining employed, involving the excavation of large open areas underground, is an important factor in the prevalence of dust in the mines. At the working faces, which may be continuous for several hundred feet, the operations of drilling, squibbing, blowing holes, shoveling, and tramming, and at times roof trimming, bowlder popping, and even blasting may be in progress at the same time. The dust made by these operations is densest at the working faces, where most of the men underground are working, but often it is carried by air currents to all parts of the mine, so that practically every man underground is in a dusty atmosphere during the entire shift. In other metal-mining districts, especially where mining is conducted on different levels, it is usual to find only part of the mine dusty, and that for only part of the day.

DRILLING.

In general, it may be said that drilling does not set in motion much of the dust made by the drill, except when the hole is being started. The bulk of the cuttings fall to the floor of the mine, but only a slight disturbance of the mine air is required to set the lighter particles in motion. Part of the cuttings remain in the drill hole, and are expelled as a cloud of dust either by squibbing or blowing the hole. Attention is directed to the fact that practically all holes drilled in these mines are approximately horizontal.

SQUIBBING.

Squibbing is one of the chief factors in setting the siliceous dust in motion. This is effected in two ways: (*a*) Dust is forcibly expelled from the drill hole, and (*b*) the vibrations set up in the mine air by the shot raise dust that has settled about the working face.

BLOWING OF DRY HOLES.

The operation of cleaning drill holes with a blast of air has been described on a previous page. The practice of blowing out holes without first wetting them is termed "blowing dry holes." More dust may be produced by it than by any other mining practice; in extreme cases the dust is so dense that the flame of a carbide lamp 15 or 20 feet distant appears as a blur of light.

BLASTING.

The blasting of one or more rounds of holes, especially where the face is dry, produces large quantities of dust. As blasting is usually done when the shift goes off, the dust so produced is chiefly harmful in that it may be set in motion when the next shift starts mining. If, as in some mines, the time between shifts is only a half or even a full hour, the dust produced by blasting will not have settled, and the second shift will suffer from it. If ventilation is good, the dust is soon removed by the air current; otherwise it hangs in suspension for several hours. The mine air after blasting is not only contaminated with dust, but contains also the gases and fumes produced by the explosives.

SHOVELING.

The quantity of dust made by shoveling depends on whether the dirt is wet, damp, or dry. If the shoveler works, as he often does, in a small puddle of water, less dust is produced than if he shovels from a dry floor. In either case the quantity of dust produced in shoveling is not excessive, but as the shoveler works with his head close to the source of the dust, and breathes deeply while working, he may take into his lungs an injurious quantity of dust during a shift.

BOWLDER POPPING AND OTHER CAUSES.

The concussion from the popping of bowlders, as in squibbing, causes violent vibrations in the mine air, which in turn stir up dust produced in other ways. Roof and pillar trimming is a minor cause of dust. If a piece of rock trimmed from the roof falls on a pile of dry dirt, some dust will be set in motion. Tramming raises appreciable quantities of dust only when the roadway is dry, the feet of the men, or mules, causing the dust to rise from the floor.

METHODS OF SAMPLING SILICEOUS DUST.

As regards the siliceous dust in the mine air, information was desired on the following points: Specific gravity of the dust particles; their size and physical and chemical characteristics; the weight of dust contained in a given volume of air; and the length of time that the dust would remain suspended.

It was a simple matter to obtain pieces of rock for the determination of specific gravity, and samples of drill cuttings for testing the physical and chemical characteristics of the rock particles. In order to determine the length of time the dust particles would remain in suspension, and the sizes of the dust particles, samples were collected at various periods of time by permitting dust to settle from the mine air on thin glass slides on which a drop of cedar oil had been placed. Cover glasses were then placed over the samples and they were set aside for examination under the microscope.

The apparatus and methods used in obtaining the samples of mine air and determining the weight of dust contained in a given volume have been described in Technical Paper 105.[a] Such work requires a suitable medium for filtering the dust-laden air, and a device that can be depended on to measure accurately the air passing through the filtering medium, simple in design, and not of great bulk.

In devising this apparatus devices that have been used for similar work in other countries were carefully studied. After conclusive experiments it was found that ordinary granulated sugar was entirely satisfactory as a filtering medium. Suction pumps, of the type used for pumping air into tires, no matter how well made, were found unsatisfactory for drawing a measured amount of air through the filtering bulb. With continued use these pumps became inaccurate on account of worn parts or from particles of dust getting into the valves and preventing them from seating properly. After various methods for measuring the air passing through the bulb containing the sugar had been considered, a device actuated by the breathing of the wearer was adopted, the volume of air breathed to be determined by receiving the exhaled air in a graduated receptacle.

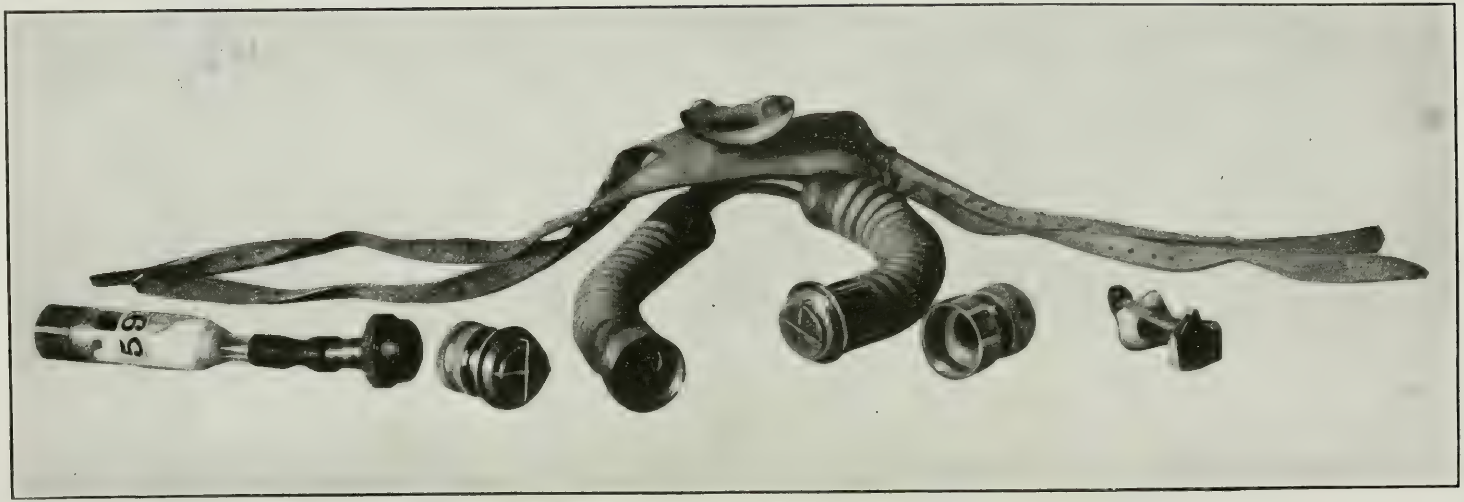
The dust sampler, as finally worked out, is shown in Plates IV and V. Plate IV shows the apparatus assembled and Plate V shows the nose clip, mouthpiece, valves, and connections. The device, which has been described in Technical Paper 105 [b], consists essentially of the following parts:

A glass bulb or container for the filtering medium (4½ inches long, 1¼ inches inside diameter at the large end, and ½ inch inside diameter at the stem). This bulb is

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among the miners in the Joplin district, Missouri, a preliminary report: Tech. Paper 105, Bureau of Mines, 1915, pp. 22 to 32.

[b] Lanza, A. J., and Higgins, Edwin, Work quoted, pp. 24–25.

APPARATUS FOR DETERMINING ROCK DUST IN MINE AIR.



DETAILS OF DUST-SAMPLING DEVICE.

partly filled with granulated sugar, which is prevented from passing into the sampling device by means of a perforated glass partition inserted just above the stem of the bulb, but at a point where the diameter is not less than 1 inch.

That part of the oxygen-breathing apparatus known as the mouthpiece, with inhalation and exhalation tubes attached. The mouthpiece may be held securely in position, when the device is in use, by means of a cap to which straps are attached. It is not necessary, however, to use a cap when one becomes familiar with the device.

A nose clip to prevent air from passing in or out of the nostrils.

What is known as a Draeger liter bag, having a capacity of 35 to 45 liters.

In order to collect a sample the apparatus is adjusted in the mouth with a dust bulb and liter bag attached. The nose clip is then placed on the nose and the person taking the sample breathes naturally. When air is inhaled the valve in the inhalation tube opens, allowing the air to pass to the lungs; at the same time the valve in the exhalation tube closes, making it impossible to draw air from the liter bag. When air is exhaled from the lungs the valve in the inhalation tube closes and that in the exhalation tube opens. In taking a sample, then, the air passes through the bulb (where the dust is intercepted by the sugar) into the lungs, and thence through the exhalation tube to the liter bag, where it is measured. Ordinarily, sufficient accuracy may be obtained by inhaling and exhaling a total of 35 liters of air. However, if the place in which the sample is taken is only slightly dusty the bag may be filled a second time, thus making a total of 70 liters of air for the sample.

In order to determine the amount of dust collected, the contents of the bulb are washed out into a weighed Gooch crucible and dried at 105° F. After successive washings with water, to dissolve and remove all of the sugar, the crucible is again dried at 105° C. and weighed. The increase in weight represents the weight of rock dust in the sample.

ACCURACY OF SAMPLING DEVICE.

In breathing a man takes a certain amount of oxygen from the air. It has been shown, by many analyses of exhaled air, that not all of the oxygen consumed is contained in the carbon dioxide given off. Under normal conditions, the ratio of carbon dioxide given off to oxygen consumed is approximately as 8 to 10, or 0.8. However, if a man exerts himself this ratio may rise to 0.9 or even 1 or slightly more. In these exceptional cases doubtless some residual carbon dioxide from the lower part of the lungs is exhaled. As exhaled air contains only 4 per cent carbon dioxide, if it be assumed that the ratio of oxygen converted into carbon dioxide to oxygen consumed is 0.8 to 1.0, the volume of the exhaled air would not be more than 1 per cent less than that of the inhaled air.[a] This difference is compensated for to some extent by the increase in temperature of the exhaled air. Owing to the variations in the factors concerned, as indicated above, no correction was made for the small error involved.

As to the velocity of the air entering the bulb, and the frequency of the inhalations, it is possible for the operator to imitate exactly the breathing of the miner at work. Thus, with the sampling bulb held near the head of the miner, the operation of this device in taking a sample is almost identical with that of the miner's respiratory

[a] 0.8 : 1 : : 4 : 5.

organs. The only difference is that in the sampling device the dust is caught in the granulated sugar, whereas in breathing the dust lodges in the lungs and air passages leading to them.

The fact that a large volume of air is taken in sampling (the liter bag may be filled as many times as deemed necessary) makes for accuracy. Although the liter bag is not elastic, there may be a small source of error in determining at just what point it should be considered to be full of air. This source of error, however, may be reduced to a minimum by practice in using the device. A sample may be taken in about two minutes, or the time may be extended by breathing alternately through the nose and through the device.

The liter bag may be tested for leaks by filling it with air and allowing it to stand for a few minutes; a leak will be indicated by loss of air. If the bag leaks, the exact location of the puncture or rent may be determined by the use of soap lather. A very small opening will cause bubbles to appear. The tubes leading to the mouthpiece may be tested for leaks by coating them with lather, holding the palm of the hand over the end of the exhalation tube and blowing through the mouthpiece. Bubbles will appear at leaky points. Thin sheet rubber, cemented on with rubber solution, makes a satisfactory patch; it is safer, however, to carry extra parts to replace those that develop leaks.

RESULTS OF THE DUST SAMPLING.

SIZING AND CHEMICAL TESTS.

Fifteen samples of drill cuttings made by drilling in the cherty flint were procured from various sheet-ground mines. The content of siliceous residue was determined in each sample; then sizing tests were made, after which the siliceous residue in that part of the sample passing through a 240-mesh screen was determined. Tests were also made to detect the presence or absence of carbonates and sulphides.

Table 4, which gives the results of the chemical analyses, shows that the content of siliceous residue in the average (unscreened) sample ranged from 70.5 to 95.3 per cent, 10 of the samples showing a content of over 90 per cent. As compared with the average samples, the determinations made on the portions passing a 240-mesh screen show more siliceous residue in some cases and less in others. All of the samples gave tests for carbonates, as indicated by effervescence with hydrochloric acid; seven showed the presence of sulphides, as indicated by the action of nitric acid.

TABLE 4.—*Results of chemical examination of drill cuttings.*

Laboratory No.	Sample No.	Siliceous residue.		Relative amount of carbonate as indicated by effervescense with hydrochloric acid.	Relative amount of sulphide present as indicated by action of nitric acid.
		Unscreened sample.	Through 240-mesh.		
		Per cent.	*Per cent.*		
20788	211	95.3	96.8	Medium	Nil.
20789	202	89.4	80.1	do	Do.
20790	215	70.5	61.3	Much	Much sulphide.
20791	422, 423	89.8	85.6	do	Little sulphide.
20792	424	91.7	93.2	Little	Nil.
20793	426	90.2	93.6	do	Much sulphide.
20794	566, 575	90.8	88.8	Medium	Do.
20795	567	94.9	95.3	do	Nil.
20796	569	95.2	97.0	Little	Do.
20797	570	94.9	96.2	Medium	Do.
20798	571, 572	86.8	83.6	Little	Little sulphide.
20799	576, 574	78.8	75.9	do	Do.
20800	580	91.2	90.6	do	Nil.
20801	590	94.8	94.6	do	Little sulphide.
20802	591	90.8	93.7	do	Nil.

Table 5 shows the results of the sizing tests. The variation in the percentage of drill cuttings passing through a 240-mesh screen indicates a variation in the dust-producing tendency of the chert in different mines. The sizes of the openings in the screens used in the sizing tests were as follows:

Standard screens used for sizing tests.

Mesh of screen.	Size of opening.		Mesh of screen.	Size of opening.	
	Inches.	*Mm.*		*Inches.*	*Mm.*
10	0.065	1.651	100	0.0058	0.147
20	.0328	.833	150	.0041	.104
35	.0164	.417	200	.0029	.074
65	.0082	.208	240	.0026	.066

TABLE 5.—*Results of sizing tests on drill cuttings.*

Laboratory No.	Sample No.	On 10-mesh.	On 20-mesh.	On 35-mesh.	On 65-mesh.	On 100-mesh.	On 150-mesh.	On 200-mesh.	On 240-mesh.	Through 240-mesh.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
20788	211	11.2	9.3	14.9	40.5	5.2	6.7	4.9	3.4	3.9
20789	202	12.0	12.5	17.5	15.3	19.1	4.5	7.2	2.2	9.7
20790	215	12.3	5.5	12.4	17.9	11.0	9.0	9.2	7.5	15.2
20791	422, 423	5.9	5.6	12.8	21.7	12.2	9.6	6.5	4.6	21.1
20792	424	34.6	15.8	16.0	11.1	5.8	3.5	2.5	.5	10.2
20793	426	20.4	12.2	14.4	14.0	8.8	7.5	4.0	.1	18.6
20794	566, 575	10.8	7.3	16.7	19.8	10.3	7.9	8.0	.1	19.1
20795	567	57.2	14.0	10.9	6.6	3.0	1.8	1.0	.1	5.4
20796	569	16.7	21.3	36.5	13.1	3.4	1.9	1.0	.1	6.0
20797	570	3.9	3.6	13.0	26.8	16.5	8.2	5.9	.4	21.7
20798	571, 572	7.3	6.5	10.4	15.1	10.7	9.1	7.0	.2	33.7
20799	576, 574	11.4	4.5	10.1	19.4	11.1	7.6	5.2	.6	30.1
20800	580	16.5	12.6	18.0	14.6	9.3	5.8	3.9	.5	18.8
20801	590	12.1	10.0	15.1	17.2	10.5	6.0	3.6	.7	24.8
20802	591	5.2	5.3	9.9	20.6	11.5	9.3	9.2	2.5	26.5

MICROSCOPIC EXAMINATION OF DUST PARTICLES.

Portions of the samples that passed the 240-mesh screen in the sizing tests were examined under the microscope by Reinhardt Thiessen, who prepared the accompanying photomicrographs (Pls. VI to VIII).

About 0.5 milligram of each sample examined was mixed or stirred into a drop of cedar oil, placed on a glass slide, and observed under the microscope. The results of Dr. Thiessen's observations, which have been given in Technical Paper 105, are repeated here.

GENERAL DESCRIPTION.

In size the dust particles varied from those averaging about 90 microns [a] down to particles that were invisible under the ordinary microscope. Some of the samples were made up chiefly of the smaller sizes, whereas others consisted mostly of the larger and intermediate sizes.

Although the larger sizes measured approximately 100 to 60 microns, there were some longer and narrower knifelike or needle-shaped particles. The smallest dimension measurable by the ordinary microscope is one-fourth to one-half micron. The smallest particle visible was about 20 millimicrons, or twenty one-thousandths of a micron.

PHYSICAL CHARACTER OF DUST PARTICLES.

In the main two kinds of particles are visible, one having a milk-white or porcelainlike look and the other being more glassy. The milky particles are generally thin, sharp edged, and irregular, often knifelike or spear point like in shape. The glassy particles are usually roughly polyhedral or spheroidal, although some are sharp edged or pointed. Of the other particles visible, some are perfect crystals, evidently calcite; others are sphalerite, galena, and pyrite. The particles are of almost every possible shape and form. The milk-white, sharp-edged particles are usually thin and scalelike; comparatively few are rounded or polyhedral. The glassy particles, on the other hand, are usually rounded or tetrahedral.

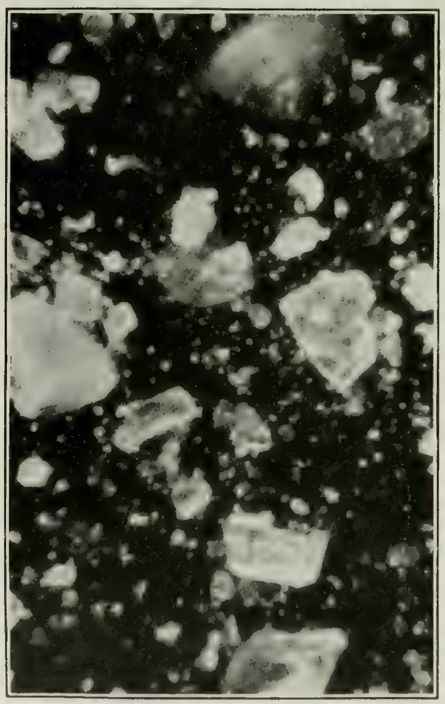
DESCRIPTION AND DISCUSSION OF PHOTOMICROGRAPHS.

In the following descriptions and discussions of the photomicrographs shown in Plates VI to VIII, and IX, *A*, the sample numbers used in Tables 4, 5, and 7 are retained.

Sample 215 (*Lab. No. 20790*).—The gradation in size is gradual. The largest particles measure about 85 microns (0.085 mm.). Sharp, angular, and irregular particles predominate.

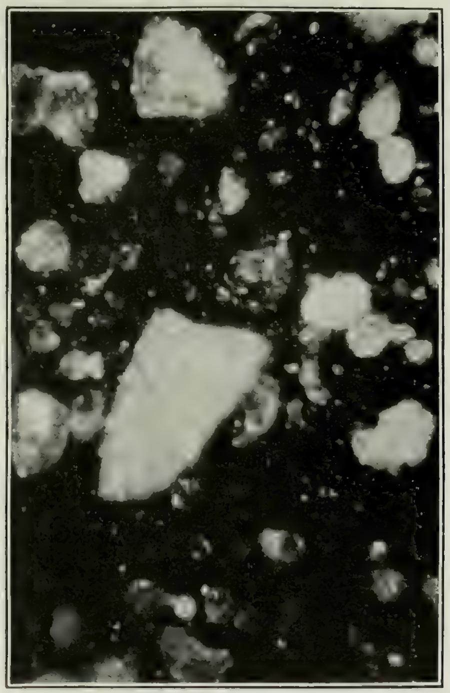
---

[a] 1 micron=one one-thousandth millimeter.



A. ROCK DUST FROM SAMPLE 215, PARTICLES MAGNIFIED 250 DIAMETERS.

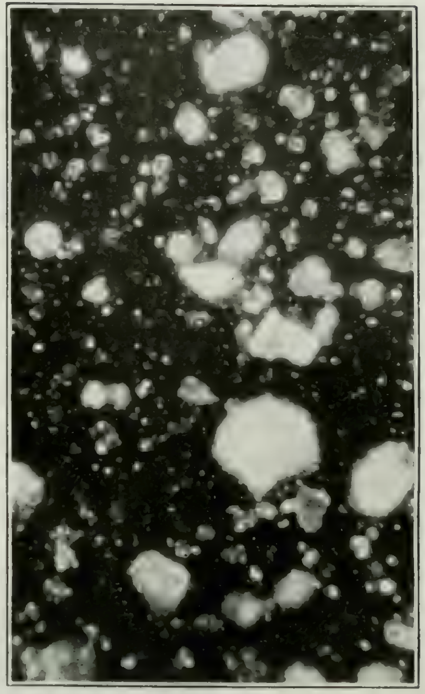
B. ROCK DUST FROM SAMPLE 215, PARTICLES MAGNIFIED 500 DIAMETERS.



C. ROCK DUST FROM SAMPLE 424, PARTICLES MAGNIFIED 250 DIAMETERS.

A. ROUNDED AND POLYHEDRAL PARTICLES FROM SAMPLE 424, MAGNIFICATION 200 DIAMETERS.

B. PARTICLES FROM SAMPLE 566, MAGNIFICATION 500 DIAMETERS.



C. ROCK DUST FROM SAMPLE 591, PARTICLES MAGNIFIED 250 DIAMETERS.

In Plate VI, *A*, magnification 250 diameters, the particle at the right is approximately 85 microns long and 48 microns wide. The smaller particles, represented by spots, are less than 1 micron. In Plate VI, *B*, magnification 500 diameters, the largest particle is approximately 56 microns in diameter.

Sample 424 (*Lab. No. 20792*).—This sample has a large proportion of the coarser particles and relatively very few small particles. Both the milky-white, irregular, sharp-edged particles and the glassy, irregular, spherical particles are shown.

Plate VI, *C*, magnification 250 diameters, shows the abundance of the large particles, and some of the milky-white, sharp-edged ones, which are very thin and spadelike.

Plate VII, *A*, magnification 200 diameters, shows the rounded and polyhedral particles.

Sample 566 (*Lab. No. 20794*).—This sample is characterized by rather sharp, angular particles, with a large number of particles ranging from medium size down to invisible—that is, from 25 microns in diameter to about 1 micron—in which the milky-white or porcelainlike are the most abundant.

The porcelainlike particles vary widely in form. Besides the sharp knifelike or angular particles, rhomboidal, tetrahedral, and even globular forms, not entirely restricted to this sample, yet more common than in others, are present.

In Plate VII, *B*, magnification 500 diameters, the clear rhombohedral particle in the lower right-hand corner is about 24 microns long, 20 microns wide, and 10 microns thick. The thin platelike particle in the lower left-hand corner, almost clear on the left-hand half, but containing millions of minute inclusions in the right half, is about 36 microns long and wide, but probably less than 0.5 micron thick. The sharp-pointed particle in the middle has a knifelike edge on the left, but is rather thick on the right.

Sample 567 (*Lab. No. 20795*).—The gradation ranges from the larger particles down to those that are invisible. The smaller ultramicroscopic particles are more abundant than in any of the other photomicrographs shown. There are also more sharp-edged particles, with even sharper edges than in any other sample. In the other samples the scalelike, sharp-edged particles are confined to the larger and medium sizes, but in these samples grade into the invisible. Two kinds of particles predominate—the milky white, which comprise the bulk of the larger sizes, but are not confined to them, and the glassy particles, which are mostly rounded, although many are sharp-edged. The milky-white particles are almost always thin, bladelike, leaflike, pointed, and some even needlelike.

In Plate VIII, *A*, the finer particles were removed in order to show the larger ones, which are angular and sharp edged. All of the particles are porcelainlike. The length of the long slender particle is approximately 230 microns and its least breadth is little more than 8 microns.

Sample 576 (*Lab. No. 20799*).—In this sample there is an almost complete absence of the milky-white material, the particles being glassy. (See Pl. VIII, *B*.) There are comparatively few large particles, the gradation being uniform.

Plate VIII, *C*, magnification 400 diameters, shows one of the largest particles that could be found in the preparation. Its largest dimension is about 80 microns. This photograph shows the relatively large proportion of the finest dust particles.

Samples 590 and 591 (*Lab. Nos. 20801 and 20802*).—These samples are composed largely of rather spheroidal or roughly polyhedral particles varying from the largest to the smallest visible. There are few milky-white particles present and also few sharp or knifelike particles.

Plate VII, *C* (No. 591), shows the general distribution and comparative sizes. The largest one is approximately 60 microns in diameter. The spherical or oval form is also shown.

Plate IX, *A* (No. 590), shows the general nature of the particles. The groundmass is clear isotropic to milky white and contains numerous finer particles, the milkiness being due to a suspension of still finer particles.

SUSPENSION OF DUST PARTICLES IN THE AIR.

A large proportion of the dust particles are less than 1 micron in diameter. How long such small particles will remain suspended in dry still air can be roughly determined from Stoke's law, the formula for which is:

$$V=\frac{2r^2\,(s-s')g}{9z}$$

V=the velocity of fall in seconds per centimeter;
r=the radius of the particle in suspension;
s=the specific gravity of the particle;
s′=the specific gravity of the medium in which it is suspended;
g=the gravity constant;
z=the viscosity coefficient of the suspending medium.

If it be assumed that a certain round particle of quartz (specific gravity 2.62) is 1 micron (or 0.0001 centimeter) in diameter, and that the air (temperature 60° F.) is free from moisture, substituting values gives:

$$V=\frac{2\times0.00005^2(2.62-0.0012)980}{9\times\frac{1970}{10^7}}=\frac{2\times0.0000000025\times(2.62\times980)}{9\times0.0001970}=0.0072$$

centimeter per second=0.432 centimeter per minute=25.92 centimeters per hour=620.08 centimeters, or 6.2 meters (20.34 feet), per day.

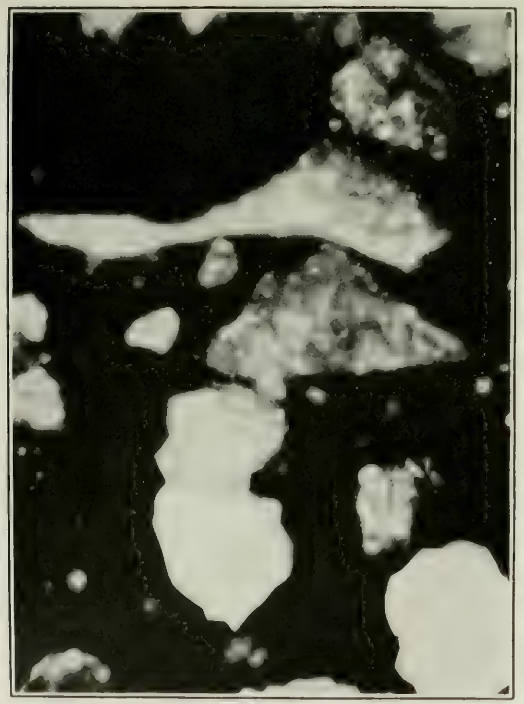
Suppose that a particle is 0.2 micron in diameter, then

$$V=\frac{2\times0.000001^2\times2.62\times980}{9\times0.000197}=0.000028$$ centimeter, or 0.00028 millimeter, per second=0.0168 millimeter per minute=1 millimeter per hour=24 millimeters (0.94 inch) per day.

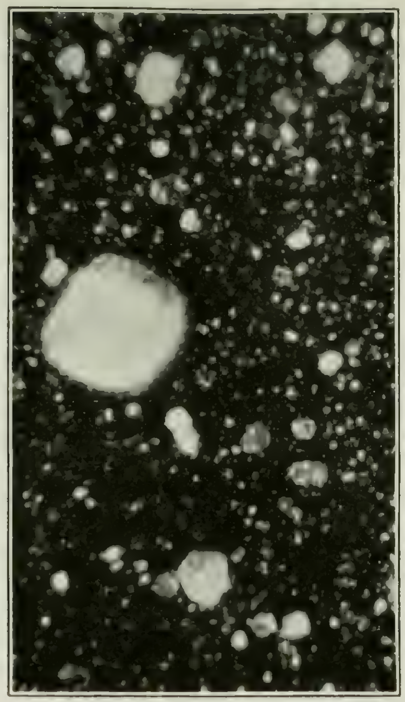
Although these theoretical calculations are of interest, it is obvious that in any attempt to determine the length of time dust particles will remain in suspension in mine air it is necessary to give proper consideration to air currents and to humidity.

MICROSCOPIC EXAMINATION OF THE PARTICLES CAUGHT ON SLIDES.

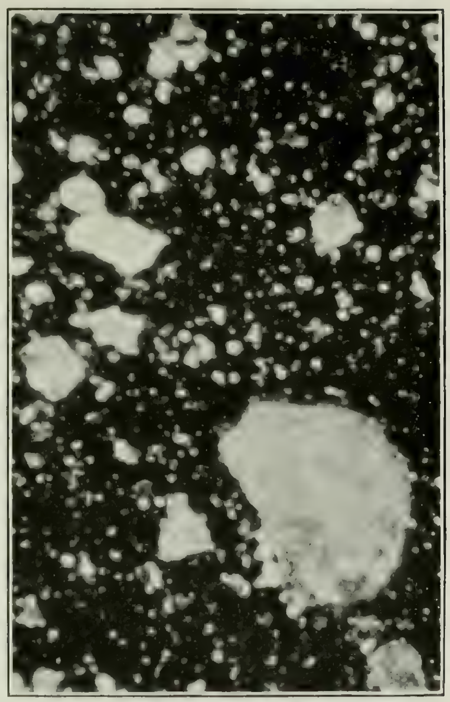
The samples that were obtained by catching dust in cedar oil on glass slides for the purpose of determining the sizes of the particles suspended in the mine air, and the length of time they would remain in suspension, were examined by Dr. Thiessen. Owing chiefly to the transparent nature of the particles, especially the smaller ones,



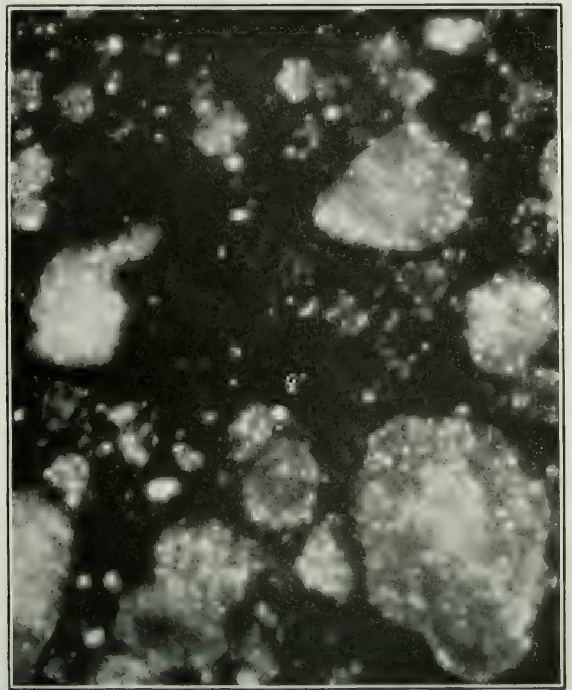
A. LARGER PARTICLES IN ROCK DUST FROM SAMPLE 567, MAGNIFICATION 250 DIAMETERS.



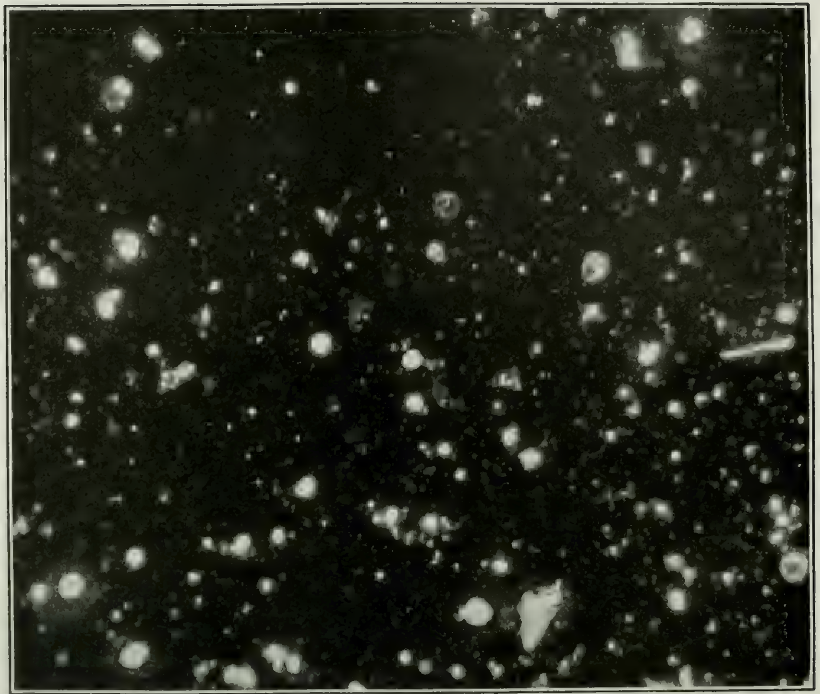
B. ROCK DUST FROM SAMPLE 576, MAGNIFICATION 250 DIAMETERS.



C. ROCK DUST FROM SAMPLE 576, SHOWING RELATIVELY LARGE PROPORTION OF FINER PARTICLES, MAGNIFICATION 400 DIAMETERS.



A. ROCK DUST PARTICLES FROM SAMPLE 590, MAGNIFIED 560 TIMES.



B. DUST FROM MINE AIR, CAUGHT ON BALSAM-COVERED PLATE, MAGNIFIED 500 TIMES.

the photomicrographs prepared from these slides, with the exception of sample 14, shown in Plate IX, *B*, were not distinct enough for the preparation of halftone reproductions. From Dr. Thiessen's report and a study of the photomicrographs, some data were obtained as to the size of the suspended dust particles and the length of time they will remain in suspension. This information is set forth in Table 6. One column shows the dimensions of the largest dust particle on the slide; in most of the slides there was only one nearly as large as indicated. Too much importance, therefore, should not be given to this figure.

TABLE 6.—*Results of tests to show size of dust particles in mine air and duration of suspension.*

Slide No.	Mine.	Date (1915).	Length of time exposed, minutes.	Cause of dust.	Distance sample was taken from source of dust, feet.	Lapse of time between production and sampling of dust.	Size of largest dust particle on slide, microns.[a]	Remarks.[b]
1	O	April 28	10	Drilling and shoveling	100	None	20 by 25	Few particles larger than 10 microns, majority less than 5 microns.
2	O	do	10	do	30	do	20 by 25	Same as No. 1.
3	O	do	18	do	30	do	20 by 17	Majority of particles less than 5 microns.
4	O	do	10	do	30	do	50 by 70	Larger percentage over 10 microns.
5	H	April 30	10	do	50	do	10 by 10	Nearly all less than 5 microns.
6	H	do	10	do	125	do	50 by 55	More larger particles than in Nos. 3 and 5.
7	H	do	10	do	125	do	50 by 40	Similar to No. 6.
8	H	do	10	do	125	do	10 by 10	Many particles between 5 and 10 microns.
9	G	May 1	10	Blasting		45 minutes	10 by 10	Few particles larger than 5 microns.
11	G	do	10	do		1 hour		Do.
12	G	do	10	do		1 hour 20 minutes	10 by 8	Do.
14	G	do	10	do		1 hour 40 minutes	10 by 5	Increasing number of particles from 1 to 2 microns.
16	G	do	60	do		2 hours	10 by 5	Similar to No. 14, but more particles of smaller sizes.
17	G	do	10	do		2 hours 30 minutes	9 by 6	Similar to No. 16.
18	G	do	20	do		3 hours	5 by 5	Gradual decrease in sizes.
19	G	do	60	do		do		Similar to Nos. 17 and 18, but more smaller particles.
20	G	do	20	do		3 hours 40 minutes		Large number of particles still smaller than in No. 19.
21	G	do	60	do		4 hours		Similar to No. 2, size decreasing and number greatly increased.
22	G	do	20	do		4 hours 20 minutes	5 by 3	Countless numbers of particles from 1 micron to submicroscopic size.

[a] 1 micron = 0.001 millimeter.

[b] The number of microns refers to the greatest dimension.

The physical characteristics of the dust particles are practically the same as indicated on pages 25 and 26. In all cases the places where the samples were taken were poorly ventilated; air currents were sluggish or entirely lacking.

Slides 1 to 8 represent general conditions underground from 30 to 125 feet from the working face.

Slides 9 to 22 were taken at various intervals after blasts in order to determine the length of time the particles of various size would remain suspended in the mine air. The temperature where these exposures were made was 62° F. and the relative humidity ranged from 95 to 100 per cent. Most of the time there was visible water vapor in the air, and this doubtless hastened the settling of the dust particles. The photomicrographs show a gradual decrease in the size of the particles, and a corresponding increase in the percentage of small particles present toward the end of this experiment. None of the photomicrographs shows any great number of particles larger than 5 microns, those as large as 10 microns being only occasionally seen. On slides 17 to 22 there appeared countless numbers of particles 0.1 to 0.2 microns in diameter. It is worthy of note that samples obtained with the mouth-breathing apparatus at the time slides 21 and 22 were prepared showed no dust. This is not to be wondered at, as the dust particles were almost submicroscopic in size.

From these experiments it appears that dust particles with dimensions of 50 to 70 microns, and more, will settle within a few minutes. However, where mining operations that make dust are continuous, these larger sizes may be found in the air all of the time. One hour after the cessation of the work causing the dust, few particles larger than 10 microns will remain in suspension, if the air is comparatively still, the size gradually decreasing up to three hours, when the largest particle to be found will be about 5 microns in greatest dimension. After four hours few particles as large as 5 microns are to be found; a small percentage will range from 1 to 2 microns, but the bulk of the particles will range from 1 micron down to submicroscopic sizes.

SIZE OF DUST PARTICLES TAKEN INTO THE LUNGS.

In the course of the investigative work carried on by Dr. Lanza, prior and subsequent to his preliminary report,[a] many samples of sputum were collected from miners who reported for examination. These samples were centrifuged and small portions placed on glass slides, to be examined under the microscope for the presence of tubercle bacilli. The writer had an opportunity to examine a great number of these slides. Siliceous dust, in varying quantities, was

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines: Tech. Paper 105, Bureau of Mines, 1915, 48 pp.

present on all of them; the cherty flint particles were plainly in evidence, and in some cases scattering particles of zinc blende and galena were recognized.

Seven of these slides were examined by Dr. Thiessen. Following is only an abstract of that part of Dr. Thiessen's report concerning the siliceous dust on these slides:

All of the slides contain, besides the rock dust, dust of organic origin, though relatively little. The rock dust is of the same nature and appearance as that gathered in tests of the suspension of dust particles. The sizes of the particles are also approximately the same as those discussed under "Suspension." There are comparatively few particles measuring more than 10 microns in diameter, but a large number measure between about 5 and 2 microns, with rapidly increasing numbers of smaller sizes, down to particles of colloidal dimensions. It is impossible to make a fair estimate of the proportion of the smaller particles to the larger, on account of the colloidal matter present in the preparations. The amount and size of particles on the sputum slides compare favorably with photomicrograph 14 (Pl. IX, *B*), of the suspension tests.

Thus it appears that comparatively few particles larger than 10 microns in diameter reach the lungs. Without question, however, much larger particles find lodgment in the nasal and other air passages leading to the lungs. When a dry hole is blown, or a drill hole is being started, the air about the hole is filled with large particles of dust, and even chips and splinters of rock. Under such conditions much of this coarse material gets inside the nostrils, or into the mouth. Miners working in very dusty places frequently can detect grit in the mouth.

WEIGHT OF DUST IN MINE AIR.

For the purpose of determining the weight of siliceous dust in mine air under varying conditions, a total of 222 samples were collected with the mouth-breathing device. These samples are described in Tables 7 and 8. The 39 samples included in Table 7 were taken during the preliminary investigation; those in Table 8, taken subsequently, are more completely described.

TABLE 7.—*Analyses of 39 samples of siliceous rock dust taken in sheet-ground mines of the Joplin district, Mo., in November, 1914.*

[All holes drilled horizontally; all samples, except where noted, taken close to nostrils of drill man or shoveler.]

Sample No.	Laboratory No.	Name of mine.	Remarks.	Weight of dust per 100 liters of air, milligrams.
202	20453	Ice Plant	Drilling breast hole, dry	6.57
203	20454	do	Taken after squibbing	4.86
209	20455	do	do	6.00
210	20456	Gopher	Shoveling	3.71
593[a]	20457	do	do	4.57
587	20488	do	do	4.86
211	20458	Little Princess	Drilling and shoveling, 10 feet away	4.00
212[a]	20459	do	do	5.14
212A	20460	Florine	Drilling and shoveling	5.14
216[a]	20461	do	do	5.71
215	20462	Oronogo Circle	Drilling, dry	3.71
222	20463	Century	Five men shoveling, 5 to 15 feet away	4.29
564[a]	20464	do	do	3.71
419	20465	Davey No. 3	Drilling breast hole, dry	6.86
420	20466	do	do	5.14
421	20467	do	Blowing hole, damp	4.29
424	20470	do	Drilling stope hole, damp	.57
426	20472	do	Taken after squibbing	4.29
423	20469	Coahuilla	Drilling breast hole, dry	4.00
574	20483	do	Shoveling	3.60
576	20485	do	do	1.14
425	20471	Wilson	Shoveling and roof trimming	2.29
573	20482	do	Shoveling	.57
571	20480	do	Drilling breast hole, dry	3.60
572	20481	do	Blowing hole, dry	7.71
563	20473	Schoolhouse	Taken 5 minutes after blowing hole, dry	3.14
567	20476	do	Taken after squibbing	7.16
567A[b]	20477	do	do	5.71
566	20475	Wingfield	Drilling breast hole, dry	3.14
575[a]	20484	do	do	3.14
569	20478	Bertha A	do	6.29
570	20479	do	do	6.00
580	20486	Otis	Drilling stope hole, damp	2.86
578	20487	do	Drilling breast hole, dry	6.00
590	20489	A. W. C. No. 1	Drilling and shoveling	6.57
596	20490	do	Shoveling	3.60
591	20491	Little Dorothy	Drilling in heading, dry	4.57
592	20492	Electrical	Taken one-half hour after five holes had been squibbed	4.00
583[a]	20493	do	do	4.86

[a] Duplicate of preceding sample.
[b] Taken 3 minutes after sample 567 was taken.

TABLE 8.—*Description of siliceous dust samples taken*

Sample No.	Bulb No.	Mine.	Date (1915).	Time.	Where taken.	Work progressing.	Position of bulb.
40	571	A	Feb. 18	a. m. 9.20	Face northwest of shaft.	Drilling breast hole	At drillman's head.
41	593	A	...do.....	9.35	.....do	.....do	.....do
42	574	A	...do.....	9.50	.....do	.....do	.....do
43	576	A	...do.....	10.05	.....do	.....do	.....do
44	576A	A	...do.....	10.20	.....do	.....do	.....do
45	222	A	...do.....	10.25	.....do	.....do	1 foot to right and 1 foot below hole.
46	531	A	...do.....	10.35	.....do	.....do	At drillman's head.
47	532	A	...do.....	10.50	.....do	.....do	.....do
48	583	A	...do.....	11.05	.....do	.....do	.....do
49	592	A	...do.....	p. m. 2.30	30 feet from west face.	Drilling at face	5 feet from floor
50	540	A	...do.....	2.45	.....do	.....do	.....do
51	539	A	...do.....	3.00	.....do	.....do	.....do
52	538	A	...do.....	3.15	.....do	.....do	.....do
53	541	A	...do.....	3.30	.....do	.....do	.....do
54	537	A	...do.....	3.45	.....do	.....do	.....do
55	203	A	Feb. 19	a. m. 9.00	Face northwest of shaft.	Drilling breast hole	At drillman's head.
56	596	A	...do.....	9.15	.....do	.....do	.....do
57	572	A	...do.....	9.30	.....do	.....do	.....do
58	580	A	...do.....	9.45	.....do	.....do	.....do
59	566	A	...do.....	10.00	.....do	.....do	.....do
60	587	A	...do.....	10.15	.....do	.....do	.....do
61	573	A	...do.....	10.30	.....do	.....do	.....do
62	294	B	Feb. 25	p. m. 2.45	Stope No. 3	Shoveling	At shoveler's head.
63	569	B	...do.....	3.00	Stope No. 10	.....do	.....do
64	278	B	...do.....	3.15	Stope No. 4	Shoveling and drilling.	At drillman's head.
65	324	B	Feb. 26	a. m. 9.15	Stope No. 12	Shoveling	5 feet from shoveler.
66	323	B	...do.....	9.30	Stope No. 2	.....do	.....do
67	295	C	...do.....	10.10	East face	Drilling breast hole	10 feet from drillman.
68	565	C	...do.....	10.30	Northwest face	Drilling and shoveling.	At drillman's head.
69	530	C	...do.....	11.00	.....do	.....do	40 feet from face
70	293	C	...do.....	p. m. 2.15	No. 3 north heading.	Drilling breast hole	At helper's head
71	536	C	...do.....	2.30	No. 1 east heading.	.....do	At drillman's head.
72	292	C	...do.....	2.45	East face	Shoveling	At shoveler's head.
73	209	A	Mar. 1	a. m. 9.45	Headframe	Dumping bucket	Beside hoistman
74	212	A	...do.....	10.00	.....do	.....do	.....do
75	334	A	...do.....	10.15	.....do	.....do	.....do
76	291	A	...do.....	10.30	.....do	.....do	.....do
77	550	A	...do.....	10.45	.....do	.....do	.....do
78	336	A	...do.....	11.00	.....do	.....do	.....do

in sheet-ground mines of the Joplin district.

Distance of bulb from source of dust.	Air circulation.	Condition of working place.	Temperature. "Wet bulb."	Temperature. "Dry bulb."	Relative humidity.	Time consumed in taking sample.	Air taken.	Dust in sample.	Dust per 100 liters of air.	Remarks.
Ft.			*°F.*	*°F.*	*P. ct.*	*Min.*	*Liters*	*Mg.*	*Mg.*	
8	Poor..	Wet....	59.5	61	92	2	35	1.00	2.86	Samples 40 to 48 taken to show quantity of dust made drilling with piston drill and no water.
8	Poor..	Wet....	59.5	61	92	2	35	1.00	2.86	
8	Poor..	Wet....	59.5	61	92	2	35	.80	2.28	Changed drill steel.
8	Poor..	Wet....	59.5	61	92	2	35	.70	2.00	12-foot hole completed 10.10 a. m.
8	Poor..	Wet....	59.5	61	92	2	35	4.50	12.86	Started new hole 10.15 a. m.
1½	Poor..	Wet....	59.5	61	92	2	35	77.60	221.71	Taken to compare quantity of dust closer to hole.
8	Poor..	Wet....	59.5	61	92	2	35	.80	2.28	
8	Poor..	Wet....	59	61	89	2	35	.20	.57	
8	Poor..	Wet....	59	61	89	2	35	.20	.57	
30	Fair...	Dry....	58	61	84	2	35	.70	2.00	Samples 49 to 54 taken to determine average quantity of dust in air when no water was used. Compare with samples 79 to 85. 2 machines working at face; no shovelers near.
30	Fair...	Dry....	58	61	84	2	35	1.20	3.43	
30	Fair...	Dry....	58	61	84	2	35	1.30	3.71	
30	Fair...	Dry....	58	61	84	2	35	1.30	3.71	
30	Fair...	Dry....	58	61	84	2	35	.60	1.71	
30	Fair...	Dry....	58	61	84	2	35	1.00	2.86	
8	Poor..	Wet....	59.5	61.5	89	2	35	.50	1.43	Compare samples 55 to 61 with Nos. 40 to 48; conditions same except that water spray was used in hole at intervals when samples 55 to 61 were taken. New hole started 9.05 a. m.
8	Poor..	Wet....	59.5	61.5	89	2	35	.80	2.28	
8	Poor..	Wet....	59.5	61.5	89	2	35	.60	1.71	
8	Poor..	Wet....	60	61.5	89	2	35	.40	1.14	
8	Poor..	Wet....	60	61.5	94	2	35	.00	.0	Drill sticking at intervals.
8	Poor..	Wet....	60	61.5	94	2	35	.00	.0	Do.
8	Poor..	Wet....	60	61.5	94	2	35	.10	.29	Do.
3	Poor..	Wet....	60	61.5	94	5	100	.70	.70	Drill working in heading, 20 feet above point of sampling.
3	Poor..	Damp..	60.5	62	92	4	70	2.10	3.00	Some dust made by dirt coming down from heading.
6	Poor..	Wet....	60.5	62	92	4	70	......	....	Bulb broken.
7	Poor..	Damp..	60.5	62	92	5	90	.70	.80	
7	Poor..	Damp..	61	62	94	5	90	.50	.60	
(a)	Poor..	Dry....	58	61	84	2½	45	1.40	3.11	2 shovelers also working within 10 feet of sampler.
8	None..	Wet....	60	61.5	92	2½	45	1.10	2.44	Drill stopped frequently; 2 shovelers working within 10 feet of sampler.
(a)	Poor..	Wet....	60	61.5	92	2½	45	.50	1.11	
3	Poor..	Wet....	60	61.5	92	2½	45	.80	1.78	
8	Poor..	Wet....	60	61.5	92	2½	45	.20	.45	
3	None..	Damp..	59	61.5	89	2½	45	.70	1.55	
6	Good..	Damp..	35	37	83	3	45	.90	2.00	Samples 73 to 78 taken to determine quantity of dust made in dumping bucket at top of derrick. 2 men were breaking large bowlders on grizzly, 6 feet below point of sampling.
6	Good..	Damp..	35	37	83	3	45	.70	1.55	
6	Good..	Damp..	35	37	83	3	45	.50	1.11	
6	Good..	Damp..	35	37.5	87	3	45	.60	1.33	
6	Good..	Damp..	35	37.5	87	3	45	.60	1.33	
6	Good..	Damp..	35	37.5	87	3	45	.40	.90	

[a] Bulb held at various distances.

TABLE 8.—*Description of siliceous dust samples taken*

Sample No.	Bulb No.	Mine.	Date (1915).	Time.	Where taken.	Work progressing.	Position of bulb.
79	301	A	Mar. 1	*p. m.* 2.15	30 feet from west face.	Drilling at face....	5 feet from floor.....
80	325	A	...do.....	2.30	.....do.............	.....do.............	.....do.............
81	335	A	...do.....	2.45	.....do.............	.....do.............	.....do.............
82	303	A	...do.....	3.00	.....do.............	.....do.............	.....do.............
83	549	A	...do.....	3.15	.....do.............	.....do.............	.....do.............
84	302	A	...do.....	3.30	.....do.............	.....do.............	.....do.............
85	548	A	...do.....	3.45	.....do.............	.....do.............	.....do.............
86	958	D	Mar. 3	*a. m.* 9.15	Point A...........	General...........	5 feet from floor.
87	960	D	...do.....	9.30	Point B...........	.....do.............	.....do.............
88	297	D	...do.....	9.45	Point A...........	.....do.............	.....do.............
89	345	D	...do.....	10.00	Point B...........	.....do.............	.....do.............
90	957	D	...do.....	*p. m.* 2.15	Point A...........	.....do.............	.....do.............
91	954	D	...do.....	2.25	Face, near point A.	Blowing hole dry..	.....do.............
92	955	D	...do.....	2.30	Point B...........	General...........	.....do.............
93	959	D	...do.....	2.45	Point A...........	.....do.............	.....do.............
94	315	D	...do.....	3.00	Point B...........	.....do.............	.....do.............
95	951	D	...do.....	3.15	Point A...........	.....do.............	.....do.............
96	211	D	...do.....	3.30	Face, near point A.	Blowing damp holes.	.....do.............
97	304	E	Mar. 5	*a. m.* 9.30	South face, machine 5.	Drilling and shoveling.	15 feet from drillmen and shovelers.
98	305	E	...do.....	9.50	South face.........	Blowing damp holes.	5 feet from floor.
99	306	E	...do.....	10.15	125 feet from south face.	None..............	.....do.............
100	307	E	...do.....	11.00	North face.........	Drilling breast hole.	3 feet from hole.
101	308	E	...do.....	*p. m.* 2.25	200 feet from north face.	None..............	5 feet from floor.
102	309	E	...do.....	2.30	North face.........	Blowing wet stope hole.	.....do.............
103	313	E	...do.....	2.55	South face.........	Starting stope hole	.....do.............
104	317	E	...do.....	3.00	60 feet from south face.	None..............	.....do.............
105	547	E	...do.....	3.20	250 feet from south face.	.....do.............	.....do.............
106	542	F	Mar. 8	*a. m.* 10.30	Face northeast of north shaft.	.....do.............	.....do.............
107	543	F	...do.....	10.45	Face northwest of north shaft.	Drilling breast hole.	5 feet from hole and floor.
108	544	F	...do.....	11.00	Face west of north shaft.	Shoveling..........	At shoveler's head..
109	545	F	...do.....	*p. m.* 1.00	.....do.............	.....do.............	.....do.............
110	546	F	...do.....	1.40	Machine No. 8.....	Drilling roof hole..	3 feet from floor.
111	953	F	...do.....	2.00	Machine No. 5.....	.....do.............	5 feet from floor......
112	563	F	...do.....	2.15	.....do.............	.....do.............	.....do.............
113	590	F	...do.....	2.45	.....do.............	.....do.............	.....do.............
114	210	F	...do.....	3.00	Face northwest of north shaft.	.....do.............	.....do.............
115	985	G	Mar. 10	2.30	Drift 14 east.......	.....do.............	4 feet out from hole.
116	986	G	...do.....	2.45	Drift 9 east........	Shoveling..........	5 feet from floor.....
117	988	G	...do.....	3.05	Drift 5 east........	None..............	.....do.............
118	535	G	...do.....	4.30	Drift 2 north	.....do.............	.....do.............
119	316	G	...do.....	4.50	Drift 3 north......	Shoveling..........	.....do.............

in sheet-ground mines of the Joplin district—Continued.

Distance of bulb from source of dust.	Air circulation.	Condition of working place.	Temperature.		Relative humidity.	Time consumed in taking sample.	Air taken.	Dust in sample.	Dust per 100 liters of air.	Remarks.
			"Wet bulb."	"Drybulb."						
Ft.			*° F.*	*° F.*	*P. ct.*	*Min.*	*Liters*	*Mg.*	*Mg.*	
30	Fair...	Damp..	60	61.5	92	2½	45	0.60	1.33	Compare with samples 49 to 54. Samples 79 to 85 were taken at same place and under same conditions, except that sprays were in use at all drills.
30	Fair...	Damp..	60	61.5	92	2½	45	.60	1.33	
30	Fair...	Damp..	60	61.5	92	2½	45	.50	1.11	
30	Fair...	Damp..	60	61.5	92	2½	45	.50	1.11	
30	Fair..	Damp..	61.5	62.5	94	2½	45	.70	1.55	
30	Fair..	Damp..	61.5	62.5	94	2½	45	.60	1.33	
30	Fair...	Damp..	61.5	62.5	94	2½	45	.40	.90	
(a)	Good..	Dry....	60	62	89	3	45	.80	1.78	Point A was 20 feet from face northeast of mill shaft; 2 drills and 4 shovelers working within 30 feet of sampler. Point B 100 feet south of A, 10 feet from face; 2 drills and 4 shovelers working within 40 feet of sampler. Samples taken to get average conditions during day.
(a)	Good..	Dry....	60	62	89	3	45	.40	.90	
(a)	Good..	Dry....	60	62	89	3	45	.90	2.00	
(a)	Good..	Dry....	60	62	89	3	45	1.20	2.67	
(a)	Good..	Dry....	60.5	62	92	3	45	.00	.00	
10	Good..	Dry....	60.5	62	92	3	45	102.80	228.45	
(a)	Good..	Dry....	60.5	62	92	3	45	.30	.67	
(a)	Good..	Dry....	60.5	62	92	3	45	.10	.22	
(a)	Good..	Dry....	60.5	62	92	3	45	.20	.45	
(a)	Good..	Dry....	60.5	62	92	3	45	.20	.45	
10	Good..	Dry....	60.5	62	92	3	45	5.20	11.55	
15	Poor..	Dry....	58	60	89	2½	45	.90	2.00	
15	Poor..	Dry....	58	60	89	2½	45	2.30	5.11	Holes wet with squirt gun, not effective.
125	Poor..	Dry....	58	60	89	2½	45	.70	1.55	Drilling and shoveling at face, 125 feet from sampler.
3	Poor..	Dry....	59	61	89	2½	45	16.10	35.78	Bulb held close to face, on same level with hole, 3 feet to right.
200	Poor..	Dry....	60	62.5	87	2½	45	1.10	2.45	Taken 5 minutes after squibbing at face.
15	Poor..	Dry....	60	62.5	87	2½	45	.60	1.34	
10	Poor..	Dry....	60	62.5	87	2½	45	6.10	13.55	
60	Poor..	Dry....	60	62.5	87	2½	45	.00	.00	Taken 60 feet back from point at which No. 103 was taken.
250	Poor..	Dry....	60	62.5	87	2½	45	.40	.90	Taken 250 feet from working face.
40	Poor..	Wet....	53.5	54	97	2½	45	.80	1.78	Machine working in heading above, 40 feet from sampler.
5	Poor..	Wet....	61	62	94	2½	45	.70	1.55	Hole 6 feet deep; sample taken directly in front of hole.
3	Poor..	Wet....	61	62	94	2½	45	.60	1.33	
3	Poor..	Wet....	61	62	94	2½	45	.60	1.33	
5	Poor..	Dry....	61	62	94	2½	45	11.50	25.55	Hole in 4 feet; sample bulb held 4 feet below and 4 feet to right of hole.
11	Poor..	Wet....	54	55	94	2½	45	16.60	36.90	Hole in 6 feet; sample bulb held 10 feet below and 3 feet to left of hole.
20	Poor..	Wet....	54	55	94	2½	45	2.10	4.67	Taken 20 feet back from point where No. 111 was taken.
75	Poor..	Wet....	54	55	94	2½	45	2.40	5.33	Taken 75 feet back from point where No. 111 was taken.
7	Poor..	Wet....	58	60	89	2½	45	3.30	7.33	Hole in 2 feet; sample bulb held 3 feet below and 3 feet to left of hole.
4	Poor..	Damp..	59	60	94	2½	45	1.40	3.11	Sampler stood in helper's position on ladder directly in front of hole.
40	Poor..	Dry....	59	60	94	2½	45	.80	1.78	Samples 118 to 124 taken after regular squibbing, at 4 p. m., which made considerable dust in places.
30	Poor..	Dry....	58.5	60	92	2½	45	.90	2.00	
30	Poor..	Dry....	59	60	94	2½	45	1.90	4.22	
30	Poor..	Dry....	59	60	94	2½	45	1.10	2.44	

a Bulbs held at various distances.

TABLE 8.—*Description of siliceous dust samples taken*

Sample No.	Bulb No.	Mine.	Date (1915).	Time.	Where taken.	Work progressing.	Position of bulb.
				p. m.			
120	318	G	Mar. 10	5.00	Drift 5 north	Shoveling	5 feet from floor
121	322	G	...do	5.15	300 feet south of air drift.	None	...do
122	564	G	...do	5.25	250 feet south of air drift.	...do	...do
123	567	G	...do	5.35	Drift No. 11	Drilling	...do
124	967	G	...do	5.45	Drift No. 13	Shoveling	...do
125	968	G	...do	6.00	Drift north of lay-by 4.	Blowing damp holes.	...do
126	608	H	Mar. 11	2.00	Southwest face	Drilling and shoveling.	...do
127	609	H	...do	2.05	...do	Drilling roof hole dry.	At drillman's head.
128	611	H	...do	2.20	250 feet from southwest face.	None	5 feet from floor
129	612	H	...do	2.30	Northeast face	Starting stope hole	4 feet above hole
130	613	H	...do	3.00	North face	Drilling roof hole	4 feet from floor
131	615	H	...do	3.25	Northeast face	5 minutes after squibbing.	...do
132	617	H	...do	3.30	North face	Drilling roof hole	...do
133	601	G	Mar. 12	9.15	Drift No. 5	After blasting	...do
134	602	G	...do	9.30	Drift No. 7	...do	...do
135	603	G	...do	9.40	Drift No. 8	...do	...do
136	604	G	...do	9.50	Drift No. 10	...do	...do
137	605	G	...do	10.00	Drift No. 11	...do	...do
138	606	G	...do	10.05	Drift No. 13	After blasting; drilling.	...do
139	607	G	...do	10.15	Drift No. 18	After blasting	...do
				a. m.			
140	962	I	Mar. 15	10.00	Point A	General	5 feet from floor
141	969	I	...do	10.20	...do	...do	...do
142	973	I	...do	10.40	...do	...do	...do
				p. m.			
143	984	I	Mar. 15	2.00	Point A	General	5 feet from floor
144	619	I	...do	2.20	...do	...do	...do
145	987	I	...do	2.40	...do	...do	...do
146	533	I	...do	3.00	...do	...do	...do
				a. m.			
147	963	I	...do	10.10	Point B	...do	...do
148	992	I	...do	10.30	...do	...do	...do
149	995	I	...do	10.50	...do	...do	...do
				p. m.			
150	618	I	...do	2.10	...do	...do	...do
151	279	I	...do	2.30	...do	...do	...do
152	534	I	...do	2.50	...do	...do	...do
153	202	I	...do	3.10	...do	...do	...do
				a. m.			
154	961	J	Mar. 18	9.15	Face, 400 feet west of shaft.	Blowing wet hole	...do
155	980	J	...do	10.15	Face, 600 feet west of shaft.	Drilling breast hole.	5 feet out from hole
156	981	J	...do	10.25	Face, 700 feet southwest of shaft.	...do	At helper's head
157	982	J	...do	10.45	Face, 800 feet southwest of shaft.	Drilling roof hole	...do

in sheet-ground mines of the Joplin district—Continued.

Distance of bulb from source of dust.	Air circulation.	Condition of working place.	Temperature. "Wet bulb."	Temperature. "Dry bulb."	Relative humidity.	Time consumed in taking sample.	Air taken.	Dust in sample.	Dust per 100 liters of air.	Remarks.
Ft.			° *F.*	° *F.*	*P. ct.*	*Min.*	*Liters*	*Mg.*	*Mg.*	
30	Poor..	Dry....	59	60	94	2½	45	0.80	1.78	
300	Good..	Dry....	58	60.5	86	2½	45	.70	1.55	Taken 300 feet from nearest work.
250	Fair...	Dry....	58	60.5	86	2½	45	1.40	3.11	Taken 250 feet from nearest work.
50	Poor..	Dry....	59	60	94	2½	45	.90	2.00	Taken 50 feet from drills.
6	Poor..	Dry....	59	60	94	2½	45	.80	1.78	
30	None..	Wet....	59	60	94	2½	45	.90	2.00	
(*a*)	None..	Dry....	61	62	94	2½	45	.70	1.55	2 machines and 3 shovelers working; taken 15 feet from nearest machine.
8	None..	Dry....	61	62	94	2½	45	.80	1.78	Hole in 6 feet.
250	Poor..	Dry....	61	62	94	2½	45	.70	1.55	Men working at face 250 feet distant.
4	None..	Dry....	60	61	94	2½	45	8.50	19.00	No water used.
12	None..	Wet....	55	56.5	91	2½	45	.20	.44	Much water used from separate line; taken 10 feet to right of drill hole.
20	None..	Dry....	58	59	94	2½	45	5.60	12.45	Squibbed 12-foot stope hole, no water used.
30	None..	Damp..	55	56	91	2½	45	.50	1.10	Samples 133 to 139 taken to find quantity of dust made by blasting. All faces where samples were taken were shot at 8.30 p. m. Shovelers were working, and this had effect of keeping dust in motion to certain extent. All places had much dust, powder smoke, and water vapor in them.
20	Poor..	Dry....	58	60.5	86	2½	45	3.50	7.78	
20	Poor..	Dry....	58	60.5	86	2½	45	1.40	3.11	
20	Poor..	Dry....	58	60.5	86	2½	45	3.20	7.11	
(*a*)	Poor..	Dry....	58	60.5	86	2½	45	2.70	6.00	
30	Poor..	Dry....	58	60.5	86	2½	45	2.10	4.67	
18	Poor..	Dry....	58	60.5	86	2½	45	2.10	4.67	
10	None..	Wet....	59	60	94	2½	45	.10	.22	
(*a*)	Poor..	Wet ...	61	61	100	2½	45	.90	2.00	Samples 140 to 153 taken to determine general conditions in mine. Point A was 30 feet from south face. Three water drills and 6 shovelers working within 100 feet of sampler. Wet under foot and air misty.
(*a*)	Poor..	Wet ...	61	61	100	2½	45	.80	1.78	
(*a*)	Poor..	Wet ...	61	61	100	2½	45	.50	1.10	
(*a*)	Poor..	Wet....	61	61	100	2½	45	.60	1.33	Point B was 600 feet north of point A and 40 feet from north face. 5 solid steel piston drills and 7 shovelers working within 100 feet of sampler; wet underfoot. Water vapor in atmosphere at both points.
(*a*)	Poor..	Wet....	61	61	100	2½	45	1.00	2.22	
(*a*)	Poor..	Wet....	61	61	100	2½	45	.30	.67	
(*a*)	Poor..	Wet....	61	61	100	2½	45	.40	.90	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	1.00	2.22	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	.50	1.10	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	.80	1.78	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	.50	1.11	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	.10	.22	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	.20	.44	
(*a*)	Poor..	Wet....	56.5	58	91	2½	45	.40	.90	
15	Poor..	Damp .	56.5	58	91	2½	45	.70	1.55	Air hose filled with water before blowing.
5	Poor..	Damp..	56.5	58	91	2½	45	.70	1.55	
8	Poor..	Damp..	56.5	58	91	2½	45	1.30	2.88	Hole 8 feet from floor.
10	Poor..	Damp..	56.5	58	91	2½	45	6.10	13.55	Hole 10 feet from floor, coarse pieces flying.

a Bulb held at various distances.

TABLE 8.—*Description of siliceous dust samples taken*

Sample No.	Bulb No.	Mine.	Date (1915).	Time.	Where taken.	Work progressing.	Position of bulb.
158	983	K	Mar. 18	*a. m.* 11.00	Southwest face	Various kinds	20 feet from drill
159	638	J	...do	*p. m.* 1.30	Face, 400 feet west of shaft.	Drilling breast hole.	7 feet out from hole.
160	639	J	...do	2.00	Face, 600 feet west of shaft.	Shoveling	5 feet from hole
161	640	J	...do	2.30	Face, 800 feet southwest of shaft.	After squibbing	...do
162	641	J	...do	2.40	...do	...do	...do
163	642	J	...do	3.00	Face, 400 feet west of shaft.	Drilling breast hole.	10 feet out from hole
164	643	J	...do	3.05	...do	...do	2 feet out from hole
165	644	L	Mar. 22	12.50	Face, southwest of shaft.	None	20 feet from face
166	645	L	...do	1.00	...do	Drilling and shoveling.	3 feet from floor
167	646	L	...do	1.50	Face, south of shaft.	...do	4 feet from floor
168	647	L	...do	2.15	Face, southwest of shaft.	Shoveling	3 feet from floor
169	648	L	...do	2.30	...do	...do	...do
170	649	L	...do	2.45	...do	...do	...do
171	620	L	...do	3.00	...do	...do	...do
172	621	L	...do	3.15	...do	...do	...do
173	622	L	...do	3.55	...do	None	4 feet from floor
174	623	L	...do	4.05	Face, west of shaft	After squibbing	...do
175	624	L	...do	4.15	...do	...do	...do
176	625	L	...do	4.25	...do	...do	...do
177	633	L	...do	4.40	...do	...do	...do
178	637	L	...do	5.00	...do	...do	...do
179	869	M	Mar. 23	1.20	Northeast face	Various kinds	...do
180	872	M	...do	1.50	Station northeast of shaft.	...do	...do
181	873	M	...do	2.00	...do	...do	...do
182	874	M	...do	2.15	...do	...do	...do
183	889	M	...do	2.25	...do	...do	...do
184	890	M	...do	2.35	...do	...do	...do
185	892	M	...do	2.45	...do	...do	...do
186	898	M	...do	3.00	...do	...do	...do
187	899	M	...do	3.15	...do	...do	...do
188	634	N	Mar. 24	12.50	Face, 200 feet southeast of shaft.	Drilling	...do
189	635	N	...do	1.00	Face, 250 feet southeast of shaft.	...do	...do
190	891	N	...do	1.25	Face, 350 feet east of shaft.	...do	...do
191	893	N	...do	2.15	...do	Blowing wet holes.	...do
192	894	N	...do	2.30	Face, 250 feet southeast of shaft	Drilling ...do	...do ...do
193	895	N	...do	2.45	...do	...do	5 feet from floor, 3 feet out from hole.

in sheet-ground mines of the Joplin district—Continued.

Distance of bulb from source of dust.	Air circulation.	Condition of working place.	Temperature.		Relative humidity.	Time consumed in taking sample.	Air taken.	Dust in sample.	Dust per 100 liters of air.	Remarks.
			"Wet bulb."	"Dry bulb."						
Ft.			*°F.*	*°F.*	*P. ct.*	*Min.*	*Liters*	*Mg.*	*Mg.*	
(*a*)	Poor..	Wet....	52	55	82	2½	45	0.80	1.78	3 drills and 5 shovelers working, taken 20 feet from nearest drill.
7	Poor..	Wet....	56	58.5	86	2½	45	1.40	3.11	Hole 12 feet in.
15	Poor..	Damp..	56	58.5	86	2½	45	.50	1.11	
15	Poor..	Damp..	56	58.5	86	2½	45	3.10	6.90	Taken 3 minutes after squib shot. Top layer of sugar blackened by smoke.
60	Poor..	Damp..	56	58.5	86	2½	45	1.30	2.88	Taken 13 minutes after same squib shot. Top layer of sugar blackened by smoke.
10	Poor..	Damp..	56	58.5	86	2½	45	.50	1.11	Compare with No. 164.
2	Poor..	Damp..	56	58.5	86	2½	45	.80	1.78	Compare with No. 163.
20	Poor..	Dry....	56	58.5	86	2½	45	.50	1.11	Taken 50 minutes after squib shot.
(*a*)	Poor..	Dry....	56	58.5	86	2½	45	1.00	2.22	2 shovelers 8 feet from sampler; 1 drill 12 feet.
(*a*)	Poor..	Dry....	56	58.5	86	2½	45	.70	1.55	Stood 3 feet from shoveler and 8 feet from drill.
3	Poor..	Damp..	54	58	77	2½	45	.60	1.33	Samples 168 to 172 taken at same point.
3	Poor..	Damp..	54	58	77	2½	45	.70	1.55	
3	Poor..	Damp..	54	58	77	2½	45	.50	1.10	
3	Poor..	Damp..	54	58	77	2½	45	.00	.00	
3	Poor..	Damp..	54	58	77	2½	45	.00	.00	
20	Poor..	Dry....	54	58	77	2½	45	.60	1.33	Taken 10 minutes after blowing 3 holes wet.
75	Poor..	Dry....	54	58	77	2½	45	1.80	4.00	Samples 174 to 178 were taken to determine effect of squibbing. 11 squibs were fired at 4 p. m. At 4.05, when first sample was taken, water had been turned into air line and place was being thoroughly sprinkled. Sprinkling was continued until 4.35; 4 hose were used.
75	Poor..	Dry....	55.5	56.5	94	2½	45	1.10	2.44	
75	Poor..	Damp..	55.5	56.5	94	2½	45	.70	1.55	
75	Poor..	Wet....	56	57	94	2½	45	.60	1.33	
75	Poor..	Wet....	56	57	94	2½	45	.60	1.33	
(*a*)	Good..	Wet....	57	59	89	2½	45	.50	1.10	2 shovelers 8 feet and 1 drill 50 feet from point of sampling.
(*a*)	Good..	Wet....	57	59	89	2½	45	.60	1.33	Samples 180 to 187 taken at point 20 feet from northeast face, 4 solid steel piston drills and 6 shovelers were working within 100 feet. Face, roof, and floor very wet; good air current. Squibbing and blowing holes frequently.
(*a*)	Good..	Wet....	57	59	89	2½	45	1.30	2.88	
(*a*)	Good..	Wet....	57	59	89	2½	45	.70	1.55	
(*a*)	Good..	Wet....	57	59	89	2½	45	.50	1.10	
(*a*)	Good..	Wet....	57	59	89	2½	45	.90	2.00	
(*a*)	Good..	Wet....	57	59	89	2½	45	.50	1.10	
(*a*)	Good..	Wet....	57	59	89	2½	45	1.30	2.88	
(*a*)	Good..	Wet....	57	59	89	2½	45	.80	1.78	
30	Poor..	Dry....	57	58.5	91	2½	45	.40	.90	Shovelers not working in the mine on day sample was taken.
25	Poor..	Dry....	57	58.5	91	2½	45	.90	2.00	
25	Poor..	Dry....	56	59	83	2½	45	.90	2.00	
20	Poor..	Dry....	56	59	83	2½	45	.40	.90	
25	Poor..	Dry....	57.5	58.5	94	2½	45	1.10	2.44	
3	Poor..	Dry....	57.5	58.5	94	2½	45	.2	2.67	

[a] Bulb held at various distances.

TABLE 8.—*Description of siliceous dust samples taken*

Sample No.	Bulb No.	Mine.	Date (1915).	Time.	Where taken.	Work progressing.	Position of bulb.
				p. m.			
194	896	N	Mar. 24	2.50	Face, 250 feet southeast of shaft.	Drilling	5 feet from floor, 10 feet out from hole.
195	897	N	...do...	3.00	...do	...do	4 feet from floor
196	900	G	Mar. 25	9.45	Heading No. 8	1¼ hours after blasting.	5 feet from floor
197	866	G	...do...	10.00	Heading No. 10	1½ hours after blasting.	...do
198	863	H	Apr. 7	2.25	Southwest heading.	Drilling and shoveling.	...do
199	864	H	...do...	2.30	...do	...do	...do
200	865	H	...do...	2.40	250 feet from southwest face.	None	...do
201	867	H	...do...	3.20	100 feet east of north shaft.	Shoveling	At shoveler's head
202	675	H	...do...	3.40	100 feet from northwest face.	Various places at face.	5 feet from floor
203	699	H	...do...	3.45	...do	...do	...do
204	696	H	...do...	3.50	20 feet from northwest face.	...do	...do
205	670	O	Apr. 28	1.00	20 feet from north face.	None	...do
206	699	O	...do...	1.25	20 feet from northwest face.	Shoveling and drilling.	...do
207	859	O	...do...	1.40	20 feet from north face.	10 minutes after squibbing.	...do
208	671	O	...do...	2.00	20 feet from northwest face.	Shoveling and drilling.	...do
209	672	O	...do...	2.25	...do	...do	...do
210	860	H	Apr. 30	2.40	50 feet from north face.	Shoveling and drilling at face.	...do
211	861	H	...do...	3.00	125 feet from north face.	...do	...do
212	857	H	...do...	3.18	...do	...do	...do
213	674	H	...do...	3.30	...do	...do	...do
214	966	G	May 1	4.50	Heading No. 11	None	...do
215	989	G	...do...	5.05	...do	...do	...do
216	990	G	...do...	5.25	...do	...do	...do
217	991	G	...do...	5.45	...do	...do	...do
218	992	G	...do...	6.05	...do	...do	...do
219	993	G	...do...	6.35	...do	...do	...do
220	994	G	...do...	7.10	...do	...do	...do
221	995	G	...do...	7.50	...do	...do	...do
222	998	G	...do...	8.30	...do	...do	...do

in sheet-ground mines of the Joplin district—Continued.

Distance of bulb from source of dust.	Air circulation.	Condition of working place.	Temperature. "Wet bulb."	Temperature. "Dry bulb."	Relative humidity.	Time consumed in taking sample.	Air taken.	Dust in sample.	Dust per 100 liters of air.	Remarks.
Ft.			*° F.*	*° F.*	*P. ct.*	*Min.*	*Liters*	*Mg.*	*Mg.*	
10	Poor..	Dry....	57.5	58.5	94	2½	45	0.50	1.10	
25	Poor..	Dry....	57.5	58.5	94	2½	45	.60	1.33	
20	Poor..	Dry....	58	60	89	2½	45	2.00	4.45	Compare with samples 95 to 100. Fan was running in No. 7 shaft.
20	Poor..	Dry....	58	60	89	2½	45	.00	.00	
15	Poor..	Dry....	60.5	63.5	84	2½	45	.80	1.78	
5	Poor..	Dry....	62	64	90	2½	45	.20	.45	Much water in use.
250	Poor..	Dry....	60	63	84	2½	45	.90	2.00	
4	Poor..	Wet....	60	63	84	2½	45	.00	.00	Water running on dirt.
100	Poor..	Dry....	62.5	65	87	2½	45	.60	1.33	
100	Poor..	Dry....	62.5	65	87	2½	45	1.60	3.55	3 squibs fired at 3.45 p. m.
100	Poor..	Dry....	62.5	65	87	2½	45	10.30	22.89	Shows effect of firing the 3 squibs.
......	Poor..	Wet....	61	62	94	2	42	.20	.48	
30	Poor..	Wet....	61	62	94	2	42	.60	1.43	
20	Poor..	Wet....	61	62	94	2	42	1.20	2.86	
30	Poor..	Wet....	61	62	94	2	42	.90	2.14	
30	Poor..	Wet....	61	62	94	2	42	1.40	3.33	
50	None .	Dry....	60.5	62.5	89	2	42	.60	1.43	Much powder smoke and water vapor.
125	None .	Dry....	60.5	62.5	89	2	42	.20	.48	Sampler had to retreat because of squib shots.
125	None .	Dry....	60	63	84	2	42	.50	1.19	6 squibs fired at 3.07 p. m.
125	None .	Dry....	60	63	84	2	42	1.20	2.86	Dust working back from face.
15	Poor..	Damp .	60	60	100	2	42	.80	1.90	Much powder smoke and water vapor.
15	Poor..	Damp .	60	60	100	2	42	.00	.00	Do.
15	Poor..	Damp .	60	60	100	2	42	.10	.24	Do.
15	Poor..	Damp .	60	60	100	2	42	.60	1.43	Do.
15	Poor..	Damp .	60	60	100	2	42	.60	1.43	Do.
15	Poor..	Damp .	60	60	100	2	42	.70	1.66	Much water vapor.
15	Poor..	Damp .	60	60	100	2	42	.40	.98	Do.
15	Poor..	Damp .	60	60	100	2	42	.20	.48	Do.
15	Poor..	Damp .	60	60	100	2	42	.00	.00	Do.

In studying these tables, it must be borne in mind that the same operation may produce widely varying quantities of dust in different mines. As pointed out on a previous page, the rock varies in dust-making tendency in different parts of the sheet-ground district; again, the presence or absence of water in the working place is an important factor. Ventilation also has an important effect on the time that dust may remain in suspension in the working places.

Samples taken at different hours of the day, also those taken at night, in all parts of the mines, show varying quantities of dust. In many of the mines where it was customary to squib and blow holes excessively just before loading, a far greater amount of dust was produced in the period between 3 and 4 o'clock in the afternoon. Although some of the samples taken indicate this condition, it is not brought out as clearly as it should be. Owing to the necessity of leaving the face when holes are squibbed, there was often difficulty in sampling during this period.

Due consideration should be given the fact that in taking samples close to shovelers, or beside drillmen, the mine air in the vicinity contained a certain amount of dust produced by other work. For instance, in obtaining a sample of dust produced by drilling, a hole might be blown in a near-by working place, and the dust so produced would vitiate the sampling at the drill. Such samples were rejected. In some cases, where the interference was only nominal, the samples are included in the tables with explanatory notes.

The samples show that dust is produced in wet working places as well as in dry places. By holding a carbide lamp so that the eyes are shaded, dust may be seen with ease in the light rays. However, smoke from shots or visible water vapor in a stream of light much resembles dust, a fact that may lead miners and others to believe that a working place is much dustier than it really is.

BLOWING DRILL HOLES.

Sample 91, taken at a point 10 feet from a drill hole being blown dry, showed 228.45 milligrams of dust per 100 liters of air. There is no doubt that the blowing of dry holes causes more dust than any other detail of mining. That a squirt gun is not always effective in wetting the dust before blowing holes, and that damp holes will make considerable dust, is shown by samples No. 96 (11.55 milligrams); No. 98 (5.11 milligrams); and No. 16 (4.29 milligrams). Holes that are naturally wet, or that are thoroughly wet by using a hose and nozzle, make very little dust, as shown by samples No. 102 (1.34 milligrams), No. 154 (1.55 milligrams), and No. 191 (0.90 milligrams).

DRILLING.

Samples taken to determine the quantity of dust made by drilling varied widely. The chief factors in this variation were: The amount of water made or supplied at the face, the distance from the collar of the drill hole at which the sample was taken, and the dust-producing tendency of the rock. The most important facts brought out by the samples of dust produced by drilling were the following: The greatest quantity of dust is produced when the hole is being started, decreasing as the hole becomes deeper. In general, roof holes produce more dust than breast holes, and breast holes produce more than stope holes. The quantity of dust in the samples decreases rapidly with the distance away from the drill hole. Little or no dust is produced from wet holes. These points are demonstrated by most of the samples listed in Tables 9 and 10, which contain the drilling samples embraced in Table 8.

TABLE 9.—*Data regarding samples of dust produced by drilling without water.*

Sample No.	Mine.	Distance of sample bulb from hole.	Kind of of hole.	Depth of hole.	Dust per 100 liters of air.
		Feet.		*Feet.*	*Mg.*
40	A	8	Breast	10.25	2.86
41 [a]	A	8	...do....	10.75	2.86
42 [a]	A	8	...do....	11.50	2.28
43 [a]	A	8	...do....	12.00	2.00
44 [a]	A	8	...do....	.17	12.86
45 [a]	A	1.5	...do....	.25	221.71
46 [a]	A	8	...do....	.50	2.28
47 [a]	A	8	...do....	2.00	.57
48 [a]	A	8	...do....	2.50	.57
100	E	3	...do....	1.00	35.78
103	E	10	Stope	.25	13.55
107	F	5	Breast	6.00	1.55
127	H	8	Roof	6.00	1.78
129	H	4	Stope	.17	19.00
155	J	5	Breast	6.00	1.55
156	J	8	...do....	6.50	1.30
157	J	10	Roof	.33	13.55
159	J	7	Breast	12.00	3.11
163	J	10	...do....	6.00	1.11
164 [a]	J	2	...do....	6.00	1.78
188	N	30	...do....	4.00	.90
189	N	25	...do....	4.00	2.00
190	N	25	...do....	4.00	2.00
192	N	25	...do....	6.00	2.44
193	N	3	...do....	6.50	2.67
194 [a]	N	10	...do....	6.50	1.10
195	N	25	...do....	3.00	1.33

[a] Taken at same point as preceding sample.

TABLE 10.—*Data regarding samples of dust produced by drilling wet or damp holes.*

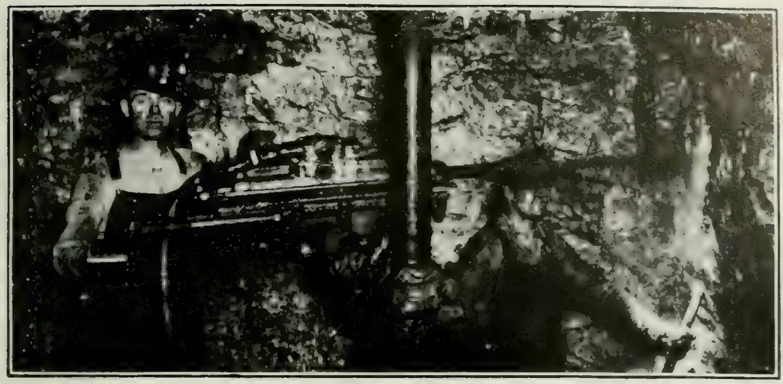
Sample No.	Mine.	Distance of sample bulb from hole.	Kind of hole.	Depth of hole.	Source of water.	Dust per 100 liters of air.
		Feet.		*Feet.*		*Mg.*
55	A	8	Breast	11.5	Spray	1.43
56 [a]	A	8	do	.17	do	2.28
57 [a]	A	8	do	1.00	do	1.71
58 [a]	A	8	do	1.50	do	1.14
59 [a]	A	8	do	2.00	do	.00
60 [a]	A	8	do	2.33	do	.00
61 [a]	A	8	do	2.00	do	.29
70	C	3	do	3.50	Damp face.	1.78
71	C	8	do	4.00	do	.45
107	F	5	do	6.00	do	1.55
111	F	11	Roof (high).	.50	Wet face	36.90
112 [a]	F	20	do	1.25	do	4.67
113 [a]	F	75	do	2.00	do	5.33
114	F	7	do	2.00	do	7.33
115	G	4	do	2.75	Damp face.	3.11
130	H	12	do	3.00	Spray	.44
132	H	30	do	1.50	Damp face.	1.10
A [b]	I	30	Various			1.43
B [c]	I	40	do			1.11
155	J	5	Breast	3.00	Damp face.	1.55
156	J	8	do	7.00	do	2.88
157	J	10	Roof	1.00	do	13.55
163	J	10	Breast	6.00	do	1.11
164 [a]	J	2	do	6.00	do	1.78

[a] Taken at same point as preceding sample.
[b] Sample A was average of samples 140 to 146; shoveling and drilling with water drills in progress. (See Table 8.)
[c] Sample B was average of samples 147 to 153; shoveling and drilling with solid steel piston drills in progress; face very wet. (See Table 8.)

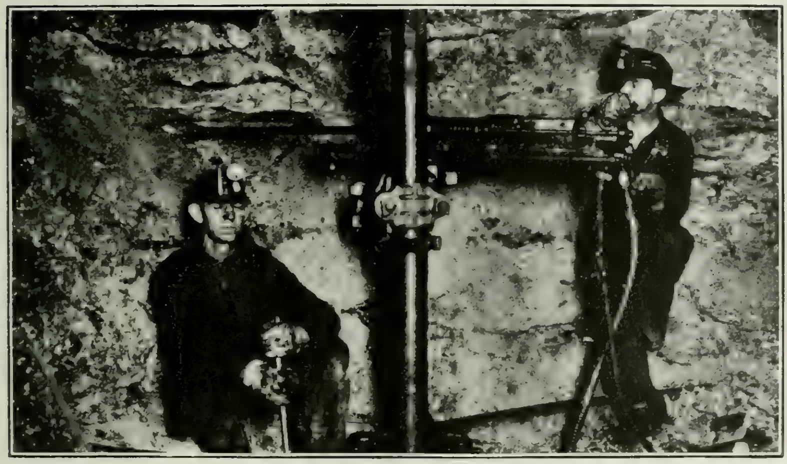
Samples 40 to 48 and 55 to 61 afford an interesting comparison as to the quantity of dust made by a piston drill working without water (see Pl. X, *A*) and the same drill working while water from a nozzle was played into the hole from time to time. The samples were taken at intervals of 15 minutes. The results have been arranged in the following table for convenient comparison:

Results of drilling with a piston drill with and without water in the hole.

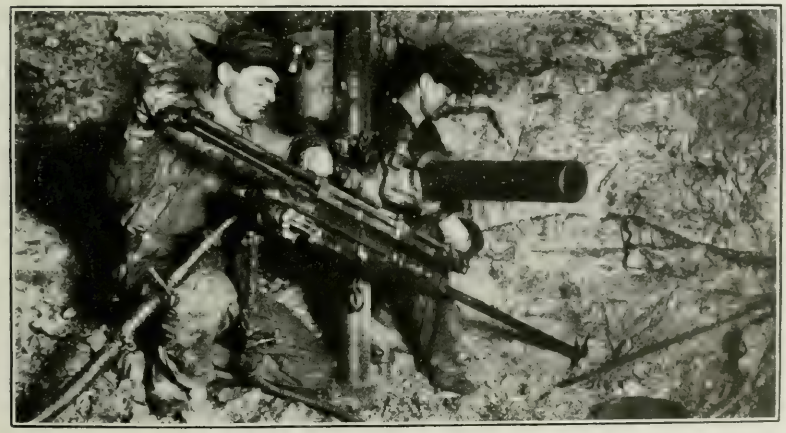
Sample No.	Without water.		Sample No.	Using water spray.	
	Depth of hole, feet.	Milligrams of dust in 100 liters of air.		Depth of hole, feet.	Milligrams of dust in 100 liters of air.
40	10.25	2.86	55	11.50	1.43
41	10.75	2.86	56	.17	2.28
42	11.50	2.28	57	1.00	1.71
43	12.00	2.00	58	1.50	1.14
44	.17	12.86	59	2.00	.00
46	.50	2.28	60	2.33	.00
47	2.00	.57	61	3.00	.29
48	2.50	.57			
Average		3.29	Average		.99



A. DRILLING DRY HOLE WITH SOLID STEEL PISTON DRILL. NOTE DUST ON HELPER'S SLEEVE AND ON ROCK; ALSO NOTE HAZE NEAR DRILL HOLE DUE TO DUST.



B. DRILLING BREAST HOLE WITH WATER-INJECTION DRILL. NOTE CLEARNESS OF VIEW AND ABSENCE OF DUST.



C. DRILLING STOPE HOLE WITH WATER-INJECTION DRILL. NOTE CLEARNESS OF VIEW AND ABSENCE OF DUST.

It will be noted that about three and one-third times more dust was produced in drilling without water. The results for samples 46, 47, and 48 would have been higher had not the exhaust from a near-by drill carried away some of the dust. The comparison would have been even more striking had it not been for the fact that the working place in both tests was comparatively wet. All of these samples were taken near the drillman's head, 8 feet from the collar of the hole. Sample 45, which showed 221.71 milligrams of dust, was taken 1½ feet from the hole when it was only 4 inches deep. (See Table 9.) This sample obviously contained many coarse particles.

Many other samples were taken in places where drilling and other mining work were in progress. The conclusions to be drawn from all of these samples are that drilling in wet places will make some dust, though not near as much as drilling in dry places; and that dust from drilling may be practically prevented by the use of drills that provide for introducing water into the hole through the core of the drill (see Pl. X, *B* and *C*), or by the use of a spray or stream of water directed into the hole.

SQUIBBING.

For convenience in studying the results of squibbing, the following tabulation is rearranged from Table 8.

Data on dust produced by squibbing in sheet-ground mines.

Sample No.	Number of holes.	Condition of working place.	Ventilation.	Distance of bulb from face, feet.	Time between squibbing and sampling, minutes.	Milligrams of dust per 100 liters in sample.
2	1	Dry	Fair	15	3	[a]4.86
18	1	Damp	...do	15	2	4.29
27	1	Wet	Poor	15	2	7.16
28 [b]	1	...do	...do	15	5	5.71
38	1	Dry	...do	10	30	[c]4.00
131	1	...do	...do	20	5	12.45
161	1	Damp	...do	15	3	6.90
162 [b]	1	...do	...do	60	13	2.88
174	11	Dry	...do	75	5	4.00
207	1	Wet	...do	20	10	2.86

[a] Duplicate showed 6.0 milligrams.
[b] Sample taken at same place as No. 27.
[c] Duplicate showed 4.86 milligrams.

In addition to the above samples many of the general samples shown in Table 8 included dust made from squibbing. In comparing the samples taken after squibbing with those taken during drilling, shoveling, and other operations, there are two important allowances to be made—namely, the samples taken after squibbing were collected some minutes after the shot, and at distances of 15 to 75 feet from the face; whereas the samples during drilling, shoveling, etc., were procured while the operation was in progress, and usually at points closer to the source of dust. The time interval and the distance factor have

an important bearing on the quantity of dust found in the air. It is plainly seen that squibbing, next to blowing dry holes, is the chief producer of dust in the sheet-ground mines.

In nearly all of the samples obtained after squibbing the sugar in the sampling bulb was blackened by powder smoke to a depth of one-sixteenth to one-fourth inch. Sample 174 (Table 8) was taken 75 feet from the face, 5 minutes after 11 holes had been squibbed. The sample showed 4 milligrams of dust per 100 liters of air. Immediately after this sample was taken water was turned into the air line and the working places were thoroughly wet, four hoses being used. This spraying was continued without interruption for 30 minutes. Samples taken at 10-minute intervals after sample 174 was collected showed 2.44, 1.55, 1.33, and 1.33 milligrams of dust, respectively.

Inasmuch as wet holes when squibbed produce much dust, although not as much as dry holes, the use of water will not avail to abate the dust. The only remedy is to stop squibbing while the shift is at work. This procedure is simple enough as regards squibbing for chambering holes, for that work can be done as the shift leaves the mine. The chief trouble is from squib shots fired to remove obstructions from the hole when the drill steel sticks. Many of the miners claim that the amount of squibbing can be reduced, but there are cases where it must be used in order to save a hole. After careful observation for a period of several months the writer believes that squibbing is largely a matter of habit, and that the sticking of the drill can usually be remedied by aligning the drill properly. In some of the mines the practice of squibbing has been entirely eliminated; in others, it is permitted only when the hole is deep and after every effort has been made to align the drill. In such cases the abandonment of the hole might mean the loss in labor of two men for one-fourth to one-third of an entire shift. Aside from the dust it causes squibbing is a costly practice. Every time a squib shot is fired all of the shovelers, drillmen, helpers, and others in the vicinity have to seek safety behind a pillar, thus curtailing the production. If to this cost be added the cost of the explosive and fuse used, it becomes apparent that the practice of squibbing, especially in mines where much used, may be a considerable item of expense.

BLASTING.

Samples of air taken after blasting show that blasting produces even more dust than does squibbing. As pointed out on a previous page, dust from blasting becomes a menace only when one shift follows closely on the preceding one. Good ventilation, or thorough sprinkling, and the regulation of shifts in accordance with the condition of the working places, will prevent inconvenience from dust caused by blasting.

SHOVELING.

Dust samples obtained where shoveling was in progress indicate that little or no dust is produced when the dirt is wet. As much as 1.55 milligrams per hundred liters were obtained where the dirt was damp; samples where the dirt was dry contained 1.78 to 4.59 milligrams of dust. It follows that dust produced by shoveling may be largely abated by spraying the dirt pile.

GENERAL CONDITIONS.

As will be noted in Table 8, many samples were taken while two or more kinds of work were being done. In some cases an average place in the mine was selected and samples taken at intervals throughout the day. In mine "A" samples 49 to 54 were taken at 15-minute intervals 30 feet from a comparatively wet face where drilling and shoveling were in progress. Samples 79 to 85 were taken at the same point the first day after the installation of water sprays. The following tabulation of results is interesting:

Effect of spraying on quantity of siliceous dust produced by drilling and shoveling.

Without sprays.		With sprays.	
Sample No.	Milligrams of dust in 100 liters of air.	Sample No.	Milligrams of dust in 100 liters of air.
49	2.00	79	1.33
50	3.43	80	1.33
51	3.71	81	1.11
52	3.71	82	1.11
53	1.71	83	1.55
54	2.86	84	1.33
		85	.90
Average	2.90	Average	1.24

Had this face been dry to start with the amount of dust would have been still more reduced. It was noted also that three squib shots were fired during the sampling while sprays were in use, which increased the quantity of dust in the air.

Samples 62 to 66 were taken from a naturally dry mine where water sprays were in use. This mine was remarkably free from dust, the samples showing from 0.6 to 0.8 milligram, with the exception of No. 63, which showed 3 milligrams. In this case the dust was caused by large bowlders being rolled down from a high heading. This mine was visited many times, but dust was not noticeable.

Mine "H," one of the dryest and dustiest mines of the district, was sampled before and after water sprays were installed. Twelve samples taken when water was not used ranged from 1.10 to as

high as 22.89 miligrams of dust; this latter sample was taken 100 feet from the working face after several squib shots. Samples taken when sprays were used ranged from 0.00 to 1.78 milligrams. In this mine the samples were not taken at regular intervals for the purpose of obtaining an average, so that it is not possible to figure the exact effect of the use of water. However, it would probably be safe to say that the use of sprays in this mine reduced the amount of dust to one-sixth or one-eighth the amount formerly made.

Attention is directed to samples 101 (2.45 milligrams); 105 (0.90 milligram); 121 (1.55 milligrams); 122 (3.11 milligrams); and 200 (2 milligrams), all of which were taken in various mines at points 200 feet and more from the working face.

WHAT CONSTITUTES A DUSTY MINE.

The term "dusty working place" is only relative; 1 to 5 milligrams of dust per 100 liters of air will render a working place dusty; the place will be dusty, but of course more so if the air contains from 50 to 100 milligrams of dust per 100 liters. A classification such as slightly dusty, dusty, and very dusty places may be made. It seems desirable, however, to adopt a standard content for the dividing line between slightly dusty and dusty working places. Evidently such a standard can not properly be based on the minimum quantity of dust that will harm the miner's lungs; it can be said only that a small quantity of dust in the mine air will be less harmful than a larger amount. Practically all air, both inside and outside of mines, contains some dust. The most reasonable standard then appears to be one based on the quantity of dust that will remain in suspension after the best known methods have been put into use for its abatement.

It has been demonstrated in the sheet-ground mines of the Joplin district that by the proper use of water and the regulation of certain details of mining the quantity of dust in the mine air can be kept below 1 milligram per 100 liters of air; so it seems reasonable to use 1 milligram as a standard at least for the Joplin district.

In this connection it might be well to discuss further a matter that was mentioned in the preliminary report of the work in the Joplin district [a] from which the four following paragraphs are quoted:

The weight of rock dust contained in mine air in South Africa, Australia, and England [b] was found in some cases to be considerably higher than those set forth in Table 5. (See Table 7 in this report.) Haldane [c] states, as regards metal mines in

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, a preliminary report: Tech. Paper 105, Bureau of Mines, 1915, pp. 31–32.

[b] Haldane, J. S., Martin, J. S., and Thomas, R. A., Report to the Secretary of State for the Home Department on the health of the Cornish miners. 1904.

[c] Haldane, J. S., The investigation of mine air, 1908, pp. 121–122.

Cornwall, that in the air of an "end" or "rise," with a rock drill at work boring dry holes, the air commonly contains 5 to 10 milligrams of dust per 10 liters.

As pointed out previously the area of the connected open ground (on the same level) in the mines of the Joplin district is far greater than in the average metal mine. Obviously the amount of dust in a given volume of air would be much greater in a confined area, such as the face of a drift, in a raise, or in a stope than in a more open space.

Moreover in taking the dust samples in the Joplin district the sampling bulb was invariably held near the head of the miner at work, so that the results obtained are not comparable with sampling closer to the source of the dust. Obviously there will be more dust in the air near the source than at points 5 to 10 feet distant. It is conceivable that larger dust particles may be collected close to the source of the dust and that these larger particles will greatly outweigh the smaller particles that would be found in suspension farther away.

The records of the countries referred to, in extreme cases, indicated as high as ten times more dust (in comparatively confined places) than was found in the Joplin mines. It is doubtless true that there will be more dust produced per volume of air in drifts, raises, and stopes than is produced in the Joplin mines. The writer does not believe, however, for the reason stated (regarding the point at which the samples were collected), that the amount would be five or ten times greater.

Since the above statement was written all the samples included in Table 8 were taken. A small percentage of the samples contained from 50 to 100 milligrams of dust per 100 liters of air, which corresponds to the 5 to 10 milligrams per 10 liters referred to by Haldane. A study of this table shows that samples taken close to the source of dust contain much greater quantities than those taken farther away. The most striking instance is in the case of samples 45 and 46. Sample 45 was taken 1½ feet from a drill hole just being started and shows 221.71 milligrams of dust per 100 liters of air; sample 46, taken immediately afterwards, 8 feet from the hole, shows 2.28 milligrams of dust. It is thus apparent that widely varying results may be obtained in taking dust samples. It is the belief of the writer that samples taken close to the nostrils of the miner, wherever he may be in performing his duties, afford the closest approximation of conditions under which he must work. Sample 46, which was taken close to the nostrils of the drillman, 8 feet from the drill hole, shows that this miner was breathing air that contained 2.28 milligrams of dust per 100 liters; consequently it would be misleading and erroneous to consider sample 45 (221.71 milligrams) as representative of this working place.

ATTEMPTS TO ABATE SILICEOUS DUST IN THE MINES.

When C. M. Harlan, W. W. Holmes, and I. L. Burch entered on their duties in 1913 as deputy State mine inspectors for the Joplin district they were instructed to do all they could to abate siliceous dust and to improve sanitary conditions generally in and about the mines of the district. Although the inspectors made every effort to better conditions they were only partly successful, as there was no law

under which their recommendations could be enforced. A few operators installed water lines and adopted certain other precautionary measures, but in the main the mines remained as dusty as before. Even in mines where water lines were installed it was found difficult to induce the miners to use the water for spraying. In spite of the difficulties under which they labored, the mine inspectors were insistent in their efforts to abate the siliceous dust. When the representatives of the Federal Government began their work the mine inspectors were anxious to assist and cooperate in furthering the work that they had started.

COOPERATIVE WORK OF FEDERAL AND STATE OFFICIALS.

This cooperative work between the Federal Government and the State of Missouri began with the arrival at Joplin, on November 7, 1914, of representatives of the Public Health Service and of the Bureau of Mines. In the course of the campaign for the improvement of sanitary conditions in and about the mines, which was intensively prosecuted for about four months, the Government representatives were given the active and earnest support of the State mine inspectors, civic organizations, mine operators, and, toward the last, the miners. The outstanding features of the campaign were the organization of the Southwestern Missouri Mine Safety and Sanitation Association, the preliminary report of the Government representatives, the effects of publicity and educational work, passage of laws relating to sanitation in and about mines, and the final vigorous and successful attempts to improve sanitary conditions.

SOUTHWESTERN MISSOURI MINE SAFETY AND SANITATION ASSOCIATION.

Early in the investigation it was recognized that an organization of operators would be of great value in furthering sanitary work in and about the mines. At a meeting of prominent operators the project was discussed and the result was the organization, during the latter part of November, 1914, of the Southwestern Missouri Mine Safety and Sanitation Association. Shortly thereafter a large hall in Webb City was obtained by the association as a meeting place, where luncheons were served every Thursday, after which business sessions were held. A secretary was employed to look after the affairs of the association.

Before the end of April, 1915, the association had enrolled 31 active, 30 associate, and 17 honorary members. The luncheons were attended by from 70 to 90 members and guests. On various occasions the business meetings were enlivened by addresses on subjects of interest, made by men of prominence.

The association appointed a special committee on sanitation, the members of which gave much time and thought to the betterment of sanitary conditions about the mines.

PRELIMINARY REPORT OF THE FEDERAL REPRESENTATIVES.

On the completion of the preliminary investigation, December 6, 1914, a report with recommendations was made to the operators of the district, through the Southwestern Missouri Mine Safety and Sanitation Association. A preliminary report was then prepared for publication by the Bureau of Mines as Technical Paper 105,[a] abstracts of which were released to various technical periodicals and to the Joplin newspapers on February 12, 1915.

This report contained the following recommendations [b] with regard to the abatement of rock dust:

1. Provide a water supply for every working face by the laying of a separate water line.
2. Where drills are operated without water, attach to the hose leading to the face a 5 or 6 foot length of pipe with a nozzle from one-eighth to one-fourth inch in diameter. Make and enforce such regulations as will insure the use of this water spray for the purpose of wetting drill holes, the face, and the broken rock about the face. For the purpose of washing drill cuttings from drill holes, this hose may be attached to the long pipes now in use for blowing out drill holes.
3. Where there is in use some type of drilling machine that provides for water passing through the core of the drill steel into the drill holes, make and enforce regulations that will insure the spraying of the face and broken rock for short periods at such times as the drill may not be in operation. For this purpose the water hose must be uncoupled from the drilling machine; this inconvenience may be overcome, however, by the use of a tee and a short length of hose.
4. Make and strictly enforce rules against squibbing and bowlder popping while the shift is underground and against the blowing of dry holes at all times.
5. Improve ventilation by the opening of new shafts whenever practicable.

In addition to the above recommendations, the following provisions [c] were offered for consideration in the framing of State laws dealing with sanitation in and about the mines:

1. That all operators of dusty mines (the question as to what constitutes a dusty mine to be left to the State mine inspector) be compelled to run a water line, in addition to the air line, to each working face, and to provide water for the line.
2. That every miner be compelled to make use of the water so provided, for the purpose of wetting down the broken ore, the working faces, and the drill holes from which dust may be spread.
3. That the practice of breaking bowlders by means of powder or dynamite be prohibited, except when the shift has left the mine.
4. That the blowing of drill holes, without first thoroughly wetting them with water, be prohibited at all times.

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines: Tech. Paper 105, Bureau of Mines, 1915, 47 pp.

[b] Lanza, A. J., and Higgins, Edwin, work quoted, p. 33.

[c] Lanza, A. J., and Higgins, Edwin, work quoted, p. 44.

5. That managers or operators of mines be prohibited from maintaining a common drinking device.

In addition to the above suggested provisions the writers are of the belief that a workmen's compensation act would go far toward improving safety and sanitary conditions in the mines in the Joplin district.

RESULTS OF EDUCATIONAL WORK AND PUBLICITY.

Early in the investigation it became apparent that, in order to effect a permanent betterment of sanitary conditions, it would be necessary to obtain the cooperation of both the mine operators and the miners; and that such cooperation could be obtained if sufficient publicity were given to the ill effects of unsanitary conditions, especially the prevalence of siliceous dust in the mines. The writer, in company with Dr. A. J. Lanza, of the Public Health Service, attended many meetings of mine operators and various organizations, and talked on the subject of mine sanitation, and the cause, effect, and abatement of siliceous dust. The matter was given much publicity in daily newspapers. Miners and their families, to the number of 2,700, were addressed at three moving-picture shows. At these gatherings, in addition to films pertaining to sanitation and safety, slides made from photomicrographs of rock dust were shown. By means of talks to groups of from 25 to 50 miners at change houses, practically every miner in the sheet-ground district was reached.

At the start few miners gave evidence of interest in better sanitary conditions. However, as they began to acquire a knowledge of the ill effects of siliceous dust their attitude changed, and the miners as a whole became interested in the abatement of siliceous dust and the general improvement of conditions underground and on the surface. There were many instances of miners quitting their working places if they were not supplied with means of allaying the dust.

Many of the mine operators, without waiting for the passage of the laws requiring improved sanitary conditions, inaugurated improvements in and about the mines, such as the building of new and commodious change houses (see Pl. I, *B*), the equipment of the mines with separate water lines and sanitary drinking devices, and the regulation of the practices of squibbing and the blowing of dry holes.

LEGISLATION LOOKING TO IMPROVED SANITARY CONDITIONS.

Shortly after the preliminary investigation the mine inspectors and the sanitation committee of the association framed certain bills looking to the abatement of siliceous dust and the correction of other evils in and about the mines. Actively supported by the mine inspectors and others, these bills were enacted into law on the last day of the Missouri State legislative session, at the end of the third week in March, 1915.

These laws, which became effective July 1, 1915, are submitted herewith.

MINING LAWS OF MISSOURI, PASSED BY THE FORTY-EIGHTH GENERAL ASSEMBLY, 1914.

Mines and Mining: Inspection of Mines and Safety of Miners—Providing for Sprinkling in Lead and Zinc Mines.

Section 1. *Amending article 2, chapter 81, R. S. 1909, by adding two new sections.*—That article 2, chapter 81 of the Revised Statutes of Missouri for the year 1909 be amended by adding two new sections to be known as "section 4869a" (8469a) and "section 4869b" (8469b), providing for the maintenance of water lines for sprinkling purposes in all lead and zinc mines generating dust, prescribing certain duties of owners and employees in operating such mines and providing a punishment for violation of the provisions thereof, which sections shall read as follows:

Sec. 8469a. *Water lines to be maintained for sprinkling in certain mines generating dust—duties of inspectors, etc.*—The State mine inspectors for lead mines, zinc mines, and other mines, other than coal, are hereby authorized, empowered, and directed to thoroughly inspect all underground excavations in all such mines, as often as the inspector or either of his deputies may deem proper, for the purpose of ascertaining or discovering in the air in any such mine or mines the presence of dust in such quantities as shall be injurious to the health of employees engaged in working in such underground excavation; and upon finding dust in the air of any such mine in such quantities as shall tend to injure the health of the employees of such mine, such inspector or deputy inspector shall immediately notify the owner, managing agent, or operator of such mine, in writing, specifying the underground excavation so found to contain dust particles as aforesaid in the air thereof, and such owner, agent, or operator of such mine shall within 15 days after receiving such written notice, provide, install, equip, and thereafter at all times maintain in such mine an independent water line, fully equipped and in good serviceable working order and repair, leading up to the face of any and all drifts where such dust is produced, or so close to the face of said drifts so that by the use of suitable hose extension or sprinkling attachments to be supplied by the owner or owners of said mine, the mineral or earth in and adjoining the face of the drift or drifts of such mine can be sprinkled or wet by water from said pipe line; thereupon and thereafter every person drilling, squibbing, or blasting in said mine shall keep the face, surface, and drill holes in said drift or drifts wet or moist by the use of water from said water line to such an extent and in such a way as shall prevent, as far as possible, any dust raising from the working of any such face or from the drilling, "blowing" or "shooting" of any hole or holes; and the ground boss in charge of the underground in any such mine, so equipped with a water line, shall require all ground or dirt after being shot or blasted to be thoroughly wet or sprinkled to such an extent as shall prevent, as far as possible, any dust from arising therefrom while the employees are at work therein.

Sec. 8469b. *Penalty.*—Every owner or part owner of any such mine and every employee of the owner of any such mine, who shall violate any of the provisions of this act, shall be deemed guilty of a misdemeanor and upon conviction thereof shall be punished by a fine of not less than \$5 nor more than \$50.

Approved, March 23, 1915.

Mines and Mining: Inspection of Mines and Safety of Mines—Promoting Health and Sanitary Conditions of Lead and Zinc Miners—Providing Dressing Rooms, etc.

Section 1. *Amending Article II, chapter 81, R. S. 1909, by adding a new section thereto.*—That Article II, chapter 31 (81), of the Revised Statutes of Missouri for the year 1909, be, and the same is hereby, amended by adding a new section thereto, to be known as section 8469b, providing dressing rooms for employees of all owners and operators of lead and zinc mines, which section shall read as follows:

SEC. 8469b. *Dressing rooms to be provided—Equipment—Inspection—Penalty.*—It shall be the duty of every owner or operator of any lead or zinc mine in the State of Missouri to provide and maintain a room or building of sufficient size and dimensions and properly equipped, for the use of employees of said mines, as a dressing room and for the purpose of changing, keeping, and storing their clothes and dinner pails. Said room shall be equipped with lockers with lock and key, and said employees shall be permitted to store their clothing and dinner pails in said lockers. Sufficient washing conveniences shall be provided in said room or building for the use of said employees, and sufficient benches or seats shall be provided for the use of employees in said room or building; and said room or building shall at all times be properly heated and shall be kept in a clean and sanitary condition. It shall be the duty of the mine inspector to see that the provisions of this section are properly enforced. Any person, firm, or corporation operating a lead or zinc mine in this State failing to comply with the provisions of this section shall be guilty of a misdemeanor and upon conviction thereof shall be fined in a sum of not less than $5 or more than $25.

Approved, March 23, 1915.

MINES AND MINING: INSPECTION OF MINES AND SAFETY OF MINERS—SANITARY DRINKING DEVICES FOR USE OF EMPLOYEES.

SECTION 1. *Amending Article II, chapter 81, by adding a new section thereto.*—That Article II, chapter 81, Revised Statutes of Missouri, 1909, be, and the same is hereby, amended by adding one new section thereto, to be known as section 8469c, which said section shall read as follows:

SEC. 8469c. *Sanitary drinking devices.*—Every owner, agent, or operator of any lead or zinc mine in this State, employing 10 or more men, shall provide sanitary drinking devices for the use of their employees.

Approved, March 23, 1915.

MINES AND MINING: INSPECTION OF MINES AND SAFETY OF MINERS—INSPECTORS TO CLOSE MINES, WHEN.

SECTION 1. *Inspectors to close mines, when.*—The chief mine inspector and his assistants shall have the power, and it is hereby made their duty, to stop the operation of and close any mine or part thereof, where poisonous damps exist, where rotten ropes or unsafe cages are used, or where a safe escape way is not provided for all employees. Any person or persons violating the provisions of this section, and any member or stockhold (er) or officer of any company or corporation who shall violate the provisions of this section, shall be deemed guilty of a misdemeanor, and on conviction thereof be punished by a fine of not less than $25 nor more than $100, or imprisonment in the county jail not less than 30 days nor more than 90 days, or by both such fine and imprisonment, for each and every separate offense.

Approved, March 22, 1915.

MINES AND MINING: INSPECTION OF MINES AND SAFETY OF MINERS—PROMOTING HEALTH AND SANITARY CONDITIONS OF COAL MINERS—PROVIDING WASHHOUSES AND EQUIPMENT.

SECTION 1. *Washhouses and equipment—Sanitary conditions, etc.*—It shall be the duty of every person, corporation, or company, and of his or its agents, officers, representatives, or person or persons in charge of, owning and operating or operating as lessees a coal mine within the State of Missouri, wherein 10 or more miners are employed in digging coal to provide within six months after the approval of this act a suitable building to be used by said miners as a washhouse, of a size not to exceed 12 feet in width and 20 feet in length and one story in height, and to be located within

a reasonable distance, not to exceed 300 feet, of the shaft house of the said mine, for the accommodation of the miners who desire to use the same; said washhouse to be equipped with a stove or other heating apparatus, and if a stove be furnished that the fuel to be burned in the same to be furnished by the operator of said mine; said washhouse shall be kept in a good and sanitary condition by the miners who use the same for the purpose of washing themselves and changing clothing when going to and returning from the mine. The room for the negroes shall be separate from that for the white race, but may be in the same building. An available supply of water shall be furnished by the operator and the same shall be carried to said washhouse by the miners; the miners shall furnish their own towels, basins, and soap, and shall exercise control over and be responsible for all property by them left therein.

SEC. 2. *Liability for loss or destruction of property.*—No person, corporation, or company, its agents, officers, or representatives, furnishing such a washhouse at his or its mines as required in section 1 hereof shall be legally liable for the loss or destruction of any property left at or in said washhouse.

SEC. 3. *Penalty.*—Any person, corporation, or company, its officers or agents, failing, neglecting, or refusing to comply with the provisions of section 1 of this act shall be guilty of a misdemeanor, and shall upon conviction be fined in any sum not less than $25 nor more than $100. Each week that such person, corporation, or company fails and neglects to comply with the provisions of said section shall constitute a separate offense: *Provided*, This act shall not apply to strip-pit or steam-shovel coal mining.

Approved, March 22, 1915.

SUMMARY AND CONCLUSIONS.

The principal facts relating to the prevalence and abatement of siliceous dust in the sheet-ground mines, and the conclusions arrived at as a result of the investigative work done are summarized as follows:

1. Siliceous dust is produced in all of the sheet-ground mines in varying quantities, regardless of whether the working places are damp or dry. Even very wet mines may be dusty if excessive squibbing is permitted.

2. Dust is produced underground by drilling, squibbing, blowing dry holes, blasting, shoveling, bowlder popping, tramming, and roof and pillar trimming. The greatest quantities of dust are produced by the blowing of dry holes; next in importance are blasting, squibbing, and bowlder popping. The dust produced by blasting, however, is not often troublesome, as it is the usual practice to blast as the shift goes off duty.

3. The dust produced is densest at the working faces, but permeates all parts of the mines.

4. The dust is composed of particles of cherty flint and contains usually more than 90 per cent siliceous residue. There are two distinct kinds of dust particles, one milky white and the other transparent and glassy. The milky white particles are generally thin, sharp edged, irregular fragments, often bladelike or knifelike in shape. The glassy particles are usually roughly polyhedral or sphe-

roidal, although some are sharp-edged or pointed. The dust particles are of almost every possible shape and form, but nearly all particles have one or more sharp edges.

5. The particles of dust in the mine air range in size from those having dimensions of 70 to 80 microns to those that are invisible under the ordinary microscope. The smallest particle measurable under the microscope was from one-fourth to one-half micron. The smallest particle visible was about 20 millimicrons, 20 thousandths of a micron. The number of these smaller particles is enormous.

6. Dust particles with dimensions of 50 to 70 microns settle within a few minutes. One hour after the cessation of the operation causing the dust, in comparatively still air, few particles larger than 10 microns remain in suspension. After three hours the largest sizes remaining in suspension have a greatest dimension of 5 microns. After four hours few particles as large as 5 microns are to be found; a small percentage will range from 3 to 4 microns, but the bulk of the particles will be less than 1 micron.

7. Most of the dust particles that reach the lungs range from 2 to 5 microns, with rapidly increasing numbers of the smaller sizes; comparatively few particles with any dimension more than 10 microns are to be found. Larger dust particles, however, find lodgment in the air passages leading to the lungs, even gritty particles being intercepted in the nose and mouth.

8. In 222 samples of dusty air, the greatest quantity of dust obtained was 221.71 milligrams per 100 liters of air. A large proportion of the samples show a content in the mine air less than 10 milligrams, and the average dusty atmosphere contained from 3 to 5 milligrams per 100 liters.

9. By proper precautions, the amount of dust in the air may be kept down to 1 milligram and less per 100 liters. The requirements and precautions necessary to accomplish this end are as follows:

Improve ventilation, where practicable, by installing fans, or by properly locating new shafts. This is an important consideration.

In mines wet enough to produce only thoroughly damp dirt, prohibit squibbing and blasting while the shift is underground. In all other mines the following precautions should be observed:

(*a*) At each working face provide a water supply of sufficient head to throw a stream at least 20 feet through a nozzle one-fourth inch in diameter. The best arrangement is a main pipe line from the surface or the water column, the water being carried from the main line to the face by 1-inch wire-wrapped rubber hose.

(*b*) The water so provided may be used with any type of water-injection drill. Provision can be made also for spraying the face and broken rock by inserting a tee connection at the machine and attach-

ing a hose and nozzle. The dirt pile should be frequently wetted in order to prevent dust being raised by shovelers.

(*c*) Where drills using solid steel are employed, a pipe long enough to reach the back of the drill hole and having a nozzle formed at one end should be coupled to the rubber hose. The spray thus provided should be used often enough during drilling to keep the drill hole damp; it should also be used for spraying the working place and broken rock at sufficiently short intervals to keep them damp. The dirt pile must be kept damp.

(*d*) Prohibit the blowing of dry holes. When necessary, wash the drill cuttings from the drill holes by means of the spray.

(*e*) Prohibit blasting and squibbing while the shift is underground, or just before the time that the shift goes to work.

(*f*) Where more than one shift is worked, allow at least two hours (preferably more) between blasting at the end of a shift and the beginning of work by another shift.

(*g*) Prohibit the popping of bowlders while the shift is underground.

10. The campaign for the abatement of siliceous dust and the improvement of sanitary conditions in and about the mines was markedly successful. This outcome resulted from the educational work conducted, the cooperation of the miners, operators, and those carrying on the campaign, and the passage of State laws regulating the conduct of mining. Similar laws in other mining districts have proved ineffective. In the Joplin district the laws were effective because of the educational work, and because of both operator and miner being penalized in case of noncompliance.

NOTES REGARDING HEALTH CONDITIONS IN METAL MINES IN FOREIGN COUNTRIES.

As indicating the consensus of opinion, and to draw attention to what has been done in other countries by way of legislation, there is included here a set of notes bearing on health conditions in mines in the Transvaal, western Australia, Great Britain, and other countries.

REPORT ON HEALTH OF CORNISH MINERS.

In the report[a] to the secretary of state for the home department on the health of Cornish miners, the following summary and recommendations are set forth:

SUMMARY.

1. The death rate among miners living in Cornwall, which has always been very high in the case of men over about 40, has very greatly increased during the last few years among men of from 25 to 45.

---

[a] Haldane, J. S., Martin, J. S., and Thomas, R. A., Report to the secretary of state for the home department on the health of Cornish miners, 1904.

2. The excessive death rate is shown by the statistics to be due entirely to phthisis and other lung diseases.

3. The recent increase in the death rate is also shown to be due to the deaths of men who have worked rock drills. The great majority of these deaths are attributable to the effects of rock-drill work in the Transvaal or elsewhere abroad; but a considerable number are attributable to work in Cornwall.

4. Nearly the whole of the deaths of rock-drill men were due to "phthisis," and of the cases examined at least 74 per cent were tuberculous.

5. The predisposing cause of the present excessive mortality among metalliferous miners from lung diseases is evidently the inhalation of stone dust.

6. The dust is produced in the drilling of dry holes by rock drills, in blasting, in handling the ore, and in other ways.

7. The dust produced by rock drills can easily be prevented by even a very small water jet.[a] The dust from blasting in close ends can be laid by a powerful jet of water and air; and can in any case be avoided by the men. The inhalation of dust produced in blasting on the stopes can also be to a large extent avoided, while the dust produced in handling the ore can be mostly prevented by keeping the workings damp.

RECOMMENDATIONS.

1. That the use of percussion rock drills in hard stone without satisfactory precautions for preventing the dust being inhaled by the men be prohibited in all mines.

2. That special rules be established under the metalliferous mines regulation act by the management of every metalliferous mine, subject to the approval of the secretary of state, for the carrying on of the work in such a manner as to reduce to a minimum the inhalation of dust by the various classes of men employed in the mine.

3. That special rules be also established under the same act, rendering it obligatory on the part of owners of metalliferous mines to provide and maintain in a suitable and cleanly condition a reasonable number of sanitary receptacles for the use of men in case of necessity underground, and also on the surface; and rendering it a contravention of the act unnecessarily to pollute any part of a mine with human feces.

The three main factors directly incidental to their occupation, which combine to produce diseases among the miners on the Witwatersrand are dust, infective processes, particularly tuberculosis, and in a lesser degree the fumes rising from the use (or abuse) of explosives.[b] This statement was made by Dr. Irvine in his evidence before the mining regulations commission in May, 1908, and with that statement there must be universal agreement.

Dust.—This constitutes the greatest danger which the underground worker has to combat. The sources of dust are: (*a*) Rock drilling, (*b*) blasting, (*c*) handling of rock. It must be acknowledged that the proper use of water in conjunction with rock drilling effectually allays the dust generated during the operation. In the face of this acknowledged fact, it is astounding that to-day this remedy has not, in many of our mines, been completely carried out. The proper use of water implies: (1) An adequate supply of clean water, (2) efficient application of the same.

With regard to this point, the law already has the power to insist on its enforcement (mines and worker's regulations, act 146, an amendment published in Government Notice No. 1278 of 1908.)

[a] A jet with an orifice one-twentieth inch in diameter directed into the hole was recommended by the signers of the report. It may be pointed out, however, that this was prior to the time of drilling machines furnishing water through the core of the drill.

[b] Penlerick, S., Ventilation and health conditions in the mines of the Witwatersrand: Jour. Chem. Met. and Min. Soc. South Africa, vol. 10, 1910, p. 59.

MINING REGULATIONS IN SOUTH AFRICA.

The following extract [a] from an article in the Mining Magazine discusses provisions of the mines regulation act of 1912, that relate to rock-dust conditions in South Africa mines:

The new mines regulation act embodied in act No. 12 of 1911, to consolidate and amend laws in force in the Union of South Africa, relating to the operations of mines, works, and machinery, and to certificates of competence, came into force on December 1, 1911. The old laws of the Provinces of Natal, Cape Colony, and Orange Free State are either wholly or partly repealed.

The new regulations make a water spray or some other suitable method for allaying and removing the dust imperative.

MINING REGULATIONS OF NEW ZEALAND.

The mining act of 1906, No. 120, New Zealand (sec. 241) provides as follows:

In every case where quartz or other substances are crushed in a dry state, or where rock drills are used, there shall at all times be used in and about the battery or place where such crushing or drilling is done such appliances as in the opinion of the inspector shall effectually keep the air pure and prevent dust circulating in the place where such operations are being carried on, and for this purpose an adequate supply of water shall be provided: *Provided*, That where either the owner or workmen's inspector is dissatisfied with the opinion of the inspector an appeal shall lie to the warden, whose decision shall be final.

The act of 1910 (No. 780), entitled "An act to amend the mining act of 1908," provides (art. 9):

It shall not be lawful for the owner or manager of any mine, or for any person in charge of the mine to require any person who is employed in the mine, or applying to be employed, to be medically examined or to produce a medical certificate that he is in a good and sound state of health.

---

[a] Editorial, Mining regulations in South Africa: Mining Mag., Feb., 1912, p. 123.

PHYSIOLOGICAL EFFECTS OF SILICEOUS DUST ON THE MINERS OF THE JOPLIN DISTRICT.

By A. J. LANZA.

INTRODUCTION.

A preliminary report dealing with the prevalence of pulmonary diseases among the zinc miners of the Joplin district has been published by the Bureau of Mines as Technical Paper 105.[a] In February, 1915, the investigation upon which the preliminary report was based was renewed and continued until the end of the calendar year 1915.

In the preceding chapter Mr. Higgins has given a description of the zinc mines of the Joplin district, the nature of the ground, the causes of rock dust and conditions under which it is found, and other technical data.

Soon after the investigation was renewed, under a cooperative agreement between the United States Public Health Service and the Bureau of Mines, an office and a laboratory were established in Webb City, Mo., in which to conduct physical examinations of miners, to make microscopic examinations of samples of sputum, and to collect pertinent data. A visiting nurse was attached to the office, who, on account of long acquaintanceship in the district and wide familiarity with the miners' families, was of great service in the collection of data on housing and on family histories. The office was kept open until the close of the year 1915.

The writer desires to thank the miners of the Joplin district for their readiness to cooperate in this work; the mine operators, the State mine inspectors, and the Jasper County antituberculosis society for their constant interest and many kind services; the physicians, who encouraged their patients to come to the office for examination, and other individuals who, by their constant moral support, furthered the cause of the investigation.

EDUCATIONAL WORK.

Among the recommendations of means that should be employed for the improvement of existing conditions outlined in the conclusion of the preliminary report was the following: "Through intensive educational campaigns in the public schools, and among the miners them-

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines; a preliminary report: Tech. Paper 105, Bureau of Mines, 1915, 48 pp.

selves, disseminate information as to the harmful effects of insanitary practices and conditions, such as crowded living quarters, overwork, exposure, dissipation, the breathing of air polluted by powder fumes and siliceous rock dust, and the use of common drinking devices."

The first work undertaken by the investigators in February, 1915, was educational. Visits were made to the sheet-ground mines at the noon hour, and while the men were eating their dinner in the change houses they were addressed by both Mr. Higgins and the author. These short talks were on the causes of rock dust, its harmful effects, and how dust could be avoided, with emphasis upon the fact that, regardless of any rules or regulations in force, their salvation from pulmonary diseases rested largely with themselves. The men were urged to come to the office in Webb City for physical examination. They were encouraged to ask questions, and the extent to which they did this, together with their strict attention everywhere, evidenced their appreciation.

By direct invitation and by advertisement word was spread around the district that miners and their families would be examined free of charge at the office and would be advised as to their physical condition. In this manner there was collected a considerable amount of information as to the physical condition, not only of the men themselves, but also of their families. More than this, however, there was thus created an opportunity for doing considerable effective work among these people by direct personal advice and instruction. Every man examined was informed fully as to his physical condition. When necessary he was advised of the proper means for caring for himself and how to prevent the spread of infection to his family. He was encouraged to return for further examination or advice and was urged to bring his wife and family for examination when there was any reason to suspect that they might not be in good health. Educational literature was distributed freely at the office.

Addresses were made to the high schools in Webb City and Joplin, to the Joplin noonday lunch club, and at the weekly meetings of the southwest Missouri mine safety and sanitation association; also to the civic league of Carterville, and similar organizations. Addresses, illustrated with moving pictures and with lantern slides, showing magnified particles of rock dust obtained from air samples in the mines, were given at local theaters for the benefit of miners and their families. The local press cooperated whenever possible, and as a result of these varied efforts the attention of the community was thoroughly aroused to the points at issue.

In connection with the educational work, it is necessary to call attention to the fact that, as a result of the high prices of zinc ore that have prevailed for the past year, and the greatly increased activity that has resulted therefrom in southwestern Missouri, there has

occurred an influx of miners from other places, until at the present time (January, 1916) it is probable that there are almost twice as many men working in the sheet-ground mines as there were a year previous. Many of these men are from coal mines, some are from metal mines, and others have never mined before. The men new to mining and the coal miners are largely ignorant of the effects of breathing hard-rock dust, and if the sanitary reforms already accomplished are to be maintained these newcomers must receive instructions similar to those outlined above. The State mine inspectors make this one of their duties, and it is probable that local sanitary organizations will be able to assist in this work.

PREVALENCE AND NATURE OF PULMONARY DISEASES.

In the preliminary report mentioned above is a table showing the deaths from pulmonary tuberculosis in Jasper and other Missouri counties for the years 1911, 1912, and 1913. Briefly, this table shows that, in respect to the disease mentioned, Jasper County leads St. Francis, Green (including Springfield), Jackson (including Kansas City), and Buchanan (including St. Joseph) Counties and the city of St. Louis, in the number of deaths per 100,000 of population. The difference between Jasper County and St. Francis County is significant: Each is a metal-mining county; each employs the same class of labor; and the general conditions are about the same in both, with this exception—hard-rock dust is not present in the southeastern Missouri mines.

A system of death reports alone does not give adequate information as to the status of a chronic disease like tuberculosis in any one place, as the disease may have been contracted elsewhere. The mining population in the Joplin district that does not represent residents of Missouri is recruited mostly from Kansas and from northern Arkansas. Most of the miners who have previously followed some other occupation have been farmers. When the victims of consumption are disabled, they are apt to return home, eventually dying there, and the cause of their death is charged, so to speak, against the wrong State or county.

To gain a more accurate idea of the amount of consumption among the miners in the Joplin district, it was decided to conduct a physical examination of a large number. It was not possible to go to any mine or group of mines and examine the entire personnel, as facilities for examining men at the mines were totally lacking. Consequently, it was necessary to fall back on the plan of having the men come to the Webb City office for examination.

During the time this office was open—May 15 to December 31, 1915—over 700 miners were examined, a number of them more than once. In each case an effort was made to determine whether the

miner was suffering from chronic disease of the lungs, and whether such disease or disablement was due to tuberculosis or to miners' consumption (rock-dust consumption), or both. Other abnormalities of the lungs and heart were also noted. Before the results of these examinations are discussed the effects of hard-rock dust on the lungs may be briefly considered.

NATURE OF MINERS' CONSUMPTION.

The continuous inhalation of the exceedingly minute particles of sharp and insoluble flint that constitute the dust in the sheet-ground mines of the Joplin district produces a mechanical injury to the lungs, causing a disease peculiar to the mining industry, and known variously as miners' phthisis, miners' asthma, miners' consumption, silicosis, or, more accurately, pneumoconiosis due to siliceous rock dust. As the term "miners' consumption" has become widely prevalent in this country, and as it is descriptive of the condition itself, it will be retained throughout this report.

Mechanically produced, miners' consumption is neither contagious nor infectious. The lung, irritated, inflamed, and injured by the hard-rock dust, becomes fibroid—that is, there is developed throughout it a scarlike tissue, which interferes with the normal elasticity of the lung and prevents proper breathing. The disease may attack one or both lungs, but is usually evenly distributed on both sides. Miners' consumption has long been recognized in the mines of the Witwatersrand in South Africa, in the Bendigo district of Australia, in Cornwall, and elsewhere. As this form of consumption becomes established, there is a gradual impairment of working ability, owing to shortness of breath, with coughing, loss of weight, and weakness. There is also a disposition to "catch cold" easily, and the cold is apt to settle on the chest. The intensity of miners' consumption varies, all grades of severity being seen, depending on the nature of the dust and the length of time spent underground, or other extent of exposure. It may persist for years and tends gradually to produce total disability.

There is, however, a deeper menace than gradual disability, in that the injured lung, together with the lowered vitality of the whole body, presents an ideal site for the development of tuberculosis. When this occurs, not only is the miner threatened with an early death or, at least, a more hopeless future; but, having now a contagious disease, he becomes a source of danger to others—his fellow workmen and his family. A tuberculous infection may take place at any stage of miners' consumption, and it is the opinion of the writer that practically no cases die without its being present. At least such was the experience in southwestern Missouri. All cases examined that were obviously in a hopeless or dying condition

showed tubercle bacilli in the sputum. In other cases, either where the men were still working, or where they were disabled, tubercle bacilli were sometimes present and sometimes not.

It is a frequent occurrence in the Joplin district, and one noticed a number of times by the writer, for a miner who for some time, perhaps several years, has had an increasing shortness of breath and an increasing impairment of working ability, suddenly to "blow up" and die after an illness of a few weeks or months. Such cases showed tubercle bacilli in the sputum. A tuberculous infection, spreading with great rapidity in a favorable soil, often helped by overwork and alcoholic dissipation, had run an acute course and brought the case of miners' consumption to a conclusion. Tuberculous infection would seem to occur most often after the mechanical disease is well established, but it does occur sooner or later in most cases.

In this connection Summons[a] says:

It can safely be concluded that at the present time all Bendigo miners dying of their respiratory diseases die of tuberculosis.

The report of the miners' phthisis prevention committee of the Union of South Africa for 1912 states:[b]

In at least the great majority of cases tuberculous infection becomes toward the end superimposed upon the preexisting silicosis.

These statements coincide with the experience of the writer during this investigation.

The concomitant occurrence of tuberculous infection becomes doubly important as regards hygiene and health to a community. Thus, when a miner is finally unable to work, and more or less bedfast, and on account of his advanced disease can no longer gain admittance to a sanitarium, or has been sent home from one as hopeless, and when finally the poverty consequent on long illness has resulted in forlorn and utterly insanitary surroundings for himself and family, then is the time when his sputum is loaded with tubercle bacilli, the danger of which to his wife and children is ignored by all concerned, because, say they, "He has miners' consumption, which is not contagious like the old-fashioned kind." As regards the public health, so far as the prevention of tuberculosis is concerned, both for the benefit of the family and of the other miners with dust-injured lungs, there should exist no distinction as to the treatment of a case of miners' consumption and of a case of tuberculosis, especially in regard to the careful disposal of the sputum

---

[a] Summons, Walter, Report of an investigation at Bendigo into the prevalence, nature, causes, and prevention of miners' phthisis, 1907, p. 42; quoted in Report of Commission to Investigate the Prevalence of Miners' Phthisis and Pulmonary Tuberculosis on mines within the Union of South Africa, 1912, p. 6.

[b] Report of Commission to Investigate the Prevalence of Miners' Phthisis and Pulmonary Tuberculosis on mines within the Union of South Africa, 1912, p. 8.

in and around the home, as in any given case tubercle bacilli may appear at any time. From observation the writer is inclined to believe that certain cases may have tubercle bacilli in the sputum intermittently—that is, the bacilli may be absent at one time and present in quantities at another time. Hence, there is necessity for care at all times.

Overwork, exposure, alcoholism, and poor living conditions are the general causes of tuberculosis among working people everywhere. When we add to these the hazard of rock dust, with its consequent injury to the lungs, we have an explanation of why so many metal miners die of tuberculosis. The conditions first named are often beyond the influence of any but the individuals concerned, but the sanitation of their working places and the elimination of rock dust can be controlled by mine operators through proper supervision, legislation, and the education of all concerned. Sanitary management of mines will be an accomplished fact when both the miners and their employers realize that there is just as much connection between poor sanitation and death through disease as there is between carelessness and death through accident; only the loss of life from disease far exceeds that from accident.

RESULTS OF PHYSICAL EXAMINATION OF 720 MINERS.

In all, 720 miners were examined, and as a result of the examinations they were grouped as follows:

Results of physical examination of 720 miners.

Classification.	Number.	Per cent.	Number.	Per cent.
Seemingly well			179	24.8
Suffering from miscellaneous diseases			26	3.6
Doubtful cases			43	5.9
Suffering from tuberculosis, seemingly not connected with siliceous dust injury to the lungs			39	5.3
First stage	2	0.2		
Second stage	13	1.8		
Third stage	24	3.3		
Suffering from miners' consumption			330	45.7
First stage	120	16.6		
Second stage	142	19.7		
Third stage	68	9.4		
Suffering from miners' consumption with a tuberculous infection			103	14.7
First stage	8	1.1		
Second stage	22	3.5		
Third stage	73	10.1		
			720	

As bearing on the value of the figures given above, it should be stated that usually men who were beginning to be seriously affected

by shortness of breath and to be alarmed as to their condition were most apt to come to the office, accounting for the preponderance of men in the first and second stages of miners' consumption. When their disease was further established they often refused to be examined, dreading to be told that they were in a hopeless condition. When, however, they believed their condition was hopeless, they were inclined to come in, like drowning men clutching at a straw, hoping that they might get some relief.

It was difficult, often impossible, to get samples of sputum, for although the miners were anxious for physical examination, they did not want to be told they had "bugs" in their sputum. They themselves clearly differentiated between what they thought was miners' consumption and the "old-fashioned kind," and nearly always maintained, even on their deathbeds, when their sputum was loaded with tubercle bacilli, that they did not have "regular consumption." They were largely correct, only they failed to appreciate the dangers of infection from the "irregular" kind.

The table shows that out of 720, 472 were suffering from pulmonary disease; of these 404, or 56 per cent of the whole, were working at the time examined or up to within six months previous. There were 433, 60.4 per cent, suffering from disease of the lungs directly due to rock-dust exposure; of these, 375, or 52 per cent of the whole, were working at the time of examination, or up to within six months previous. However, these figures do not justify the statement that half of the miners in the sheet-ground district had consumption; but in view of the chronic nature of miners' consumption and of tuberculosis, it is safe to say that practically all of these were in a diseased state during the year 1914. The total number examined represents about one-fourth of all men working in sheet-ground mines up to the boom of 1915. Therefore, of all the sheet-ground miners at that time, 15 per cent had consumption. On a conservative estimate, the writer believes that the actual number of cases of miners' consumption was at least twice as great. At the present time (January, 1916) there are probably twice as many men, if not more, working in the Joplin district as formerly; and the extent of the prevalence of lung diseases now is mere conjecture.

CASES OF TUBERCULOSIS WITHOUT ROCK-DUST INJURY.

As regards the 39 men who were found to be suffering from pulmonary tuberculosis and whose lungs showed no evidence of rock-dust injury, their histories indicated that several of them were tuberculous before they started mining work.

The two men in the first stage are still working. Of the 13 men in the second stage, 10 were working at the time of examination and 3 had stopped in the previous two months. One has since become

disabled. Of the 24 men in the third stage, 6 were still working and 8 had quit at various times within the previous six months; 5 have died up to the time of writing.

CASES OF MINERS' CONSUMPTION ONLY.

The table shows that 330 miners manifested definite signs of injury to the lungs from siliceous dust, but as far as could be determined were free from tuberculous infection. Of the 120 in the first stage, 107 were still working underground and 11 had quit in the previous two months. Of the remaining 2, one had not mined for a year, the other for four years. The 13 who had quit mining were all doing some kind of surface work. In this group was a former coal miner, who probably had anthracosis before coming to the Joplin district.

Of the 142 men in the second stage, 123 were still working underground and 10 had quit the ground in the previous six months. The remaining 9 had not mined for one to six years previously. One man has since been killed, and 6, as far as is known, have stopped underground work since their examination. Two men had seemingly contracted their disease in other mining districts before coming to Missouri, and another had anthracosis when he came. Among those who no longer mine there are a teamster, a shoemaker, a machinist, a farmer, a man who works in the harvest fields, and another who runs a shooting gallery.

Of the 68 men in the third stage, 19 were still working steadily underground and 5 were working intermittently—when they were able; 22 had stopped working within the previous six months. Of the remaining 22, 11 had quit in the past year and the other 11 had not worked for periods up to seven years. Two have stopped work since being examined and 4 have died. Three are now farming or ranching, 1 works in a shoe factory, 1 is a cobbler, and 1 is a night watchman. On account of their pronounced tendency to shortness of breath, there is not much that these men can do when they leave the mines, and as a class they are entirely unfamiliar with sedentary occupations.

CASES OF MINERS' CONSUMPTION WITH A TUBERCULOUS INFECTION.

As the table shows, there were 103 men who, besides having miners' consumption, showed symptoms of tuberculosis or had tubercle bacilli in their sputum. Of the 8 in the first stage, 7 were still working underground and 1 had laid off in the previous month. Of the 22 in the second stage, 19 were still working underground and 3 had laid off within the previous two months.

Of the 73 in the third stage, 25 were still working underground, 5 worked intermittently, and 18 had quit mining within the previous six months; 12 had quit within the previous year, and the remaining

13 had not worked underground for periods ranging to eight years; 4 have stopped work since being examined, and 15 have died (as far as known). One is now a paperhanger, 1 a carpenter, and 1 drives a wagon.

DOUBTFUL CASES.

The doubtful cases include men who had symptoms resembling miners' consumption, but on examination were found also to have heart or circulatory troubles, and concerning whom, therefore, there was a legitimate doubt as to the real cause and nature of their disability. Of the 43 men in this class, 35 were still working, 6 had worked until some time in the previous six months, and the remaining 2 had not mined for some years. Two have died since examination.

MINERS SUFFERING FROM MISCELLANEOUS DISEASES.

Included among the miners examined were men who were found suffering from heart, kidney, or other chronic organic disease not involving the lungs. Of the 26 men in this group, 25 were still working and 1 had stopped two months previously.

MINERS SEEMINGLY WELL.

There were 179 men who were seemingly well, of whom 169 were still working underground when examined, 7 had laid off within the previous six months, and 2 in the previous two years.

For convenience, the cases of consumption enumerated above have been divided into three stages—first, second, and third. In the first stage of miners' consumption are included those cases in which the sufferers showed a slight or moderate tendency to shortness of breath and some diminished expansion of the chest. Generally there was some pain in the chest, coughing, and expectoration, but no marked impairment of working ability. The second stage includes cases in which the sufferers showed moderate or moderately severe shortness of breath on exertion, diminished expansion of the chest, and well-defined impairment of working ability; with or without other symptoms. Those sufferers classed as being in the third stage showed a severe shortness of breath, with more or less total disability and aggravated symptoms of various kinds.

GENERAL REMARKS ON PHYSICAL EXAMINATIONS.

Throughout these examinations, the symptoms presented were interpreted in a conservative manner, and the errors of diagnosis are in favor of the group "seemingly well." It was recognized that men who had worked underground only a short time often exhibited some shortness of breath and coughing, with irritation of the throat and the bronchial passages, owing to the unfamiliar work and the

dust and powder smoke. Effort was made not to include these cases of acute irritation of the upper air passages with those of early lung trouble. Where there was doubt, the miner was classified as seemingly well and urged to return for reexamination. Some of these cases did not return and were lost sight of and so remain as first recorded. There are not enough of them to appreciably change the percentages.

The nature of the work done seemingly has little influence on the inception of miners' consumption. Underground the bulk of the workers are either shovelers or machine men and their helpers, and all of these are equally exposed to dust. Most of the men examined, especially those who had mined for several years, had done both machine work and shoveling. A few cases of miners' consumption were noted in millmen who had not worked underground, but had inhaled the rock dust set free by the crushers.

SANITARY CONDITIONS UNDERGROUND.

PREVALENCE OF SILICEOUS DUST.

The causes of siliceous rock dust, its nature, and methods of prevention have been set forth. During the past year many mines have installed separate water lines to the heading, and the recent laws providing for the prevention and laying of dust are being complied with more and more. The miners are becoming accustomed to using water, and the efficiency of dust prevention is increasing. As a result of the educational campaign there is not much objection to the use of water by the men, and when they do fail to use it where provided such failure is rather through carelessness than intent. Now a man "blowing a dry hole" is apt to meet decided objection from those working near him. Men who do not have to work strenuously sometimes wear respirators, but there are very few who can wear them comfortably, on account of the impediment to breathing they cause, and at best respirators seem to be of little or no value, owing to the fact that they do not filter out the finer dust particles.

In a few mines fans have been installed and have aided greatly in clarifying the air. In one mine a large suction fan was placed on the surface and in another a blower fan keeps a current of air moving along the headings.

Where separate water lines are established, the "dummy" (machine helper) plays the water against and into the drill hole while the machine man runs the drill. In blowing the hole, the blowpipe is fitted into the water line instead of the air line, as formerly, and the hole is blown out from the bottom by water. When not otherwise in use, the water is allowed to run over the dirt pile, so that the dirt (ore) is wet when shoveled. This practice minimizes the likelihood

of injury from dust, both for the shoveler and for the men who work on the screen where the ore is dumped.

Drills of the type in which water is fed through hollow steels have not come into general use, but it is probable that they will gain in favor. It should be remembered that water drills will not prevent dust where promiscuous squibbing and bowlder popping are allowed. Under these circumstances there is bound to be dust in the air, regardless of the amount of water under foot or in pipes. Squibbing and bowlder popping throw into the air the finest of dust particles, the ones that have come to be recognized as most dangerous to health. Thus, a false sense of security caused by waterline equipment must be guarded against. As in other matters of public health, prevention is easier, cheaper, and more efficient than remedial measures.

Altogether, the outlook for dust prevention, as judged by what has already been accomplished, is very hopeful. On a conservative estimate there has been at least a 50 per cent improvement, and it is the opinion of the State mine inspectors that at the present rate of progress dust in the sheet-ground mines will be reduced to a minimum within a couple of years from the time the present laws were passed. There is still too much squibbing and bowlder popping, but miners who have always been their own judges as to the necessity, can not be expected to drop these practices in a short time.

It would seem that underground conditions during the night shift are not as good as they are during the day shift. There are liable to be more new men on the night shift, and their supervision is not always so strict as during the day; men on night shift are more exposed to dust caused by blasting, and although it may not be practicable to change the time of blasting, more strenuous effort should be made to lay the dust thus caused where men have to work soon afterwards.

SUPPLY OF DRINKING WATER.

Recent mining laws did away with common drinking devices. Most of the larger mines are piped with drinking water of good quality and sanitary drinking devices are usually installed. A simple device is to have an upturned pipe, with a union on the end too big to be placed in the mouth, and with a drainage valve underneath; the water comes out with sufficient force to prevent saliva accumulating in the cup.

HUMAN WASTE.

So far little progress has been made toward remedying the evil of promiscuous ground pollution in the mines. A few mines have installed chemical closets, but it is too early yet to comment on their value. In the larger mines a simple toilet system should be in-

stalled, providing sanitary privies underground, with proper removal and disposal of their contents. An efficient privy is described in Bureau of Mines Technical Paper 105.[a] Empty powder boxes are used as receptacles, and are removed daily and burned. There does not seem to be much danger of hookworm disease in these mines, owing to the comparatively low temperature, which averages 60° F., and the nature of the soil, flint and limestone. However, the present habit of ground pollution is an objectionable nuisance and an offense to decency.

METALLIC POISONING.

The possibility of miners who work in zinc and lead being poisoned by those metals was kept in mind during this investigation. As particles of both these metals are in suspension in the air of the mines in the district, it might be supposed that they would have some harmful effect. However, there was nothing at all observed to lead in any way to the conclusion that metallic posioning was responsible for diseases of miners in the Joplin district. Outside of a couple of men who had worked in smelters, no cases with a history of lead poisoning were seen. Inquiry of operators and miners who had been in the district for many years failed to establish any instance of metallic poisoning. The lead occurs as galena or lead sulphide; being insoluble, such particles as may find their way into the body are either eliminated unchanged, or, if they lodge in the lung, remain chemically inert.

EFFECT OF USE OF CARBIDE LAMPS.

As carbide lamps have an offensive smell, and as they came into common use about the time that the prevalence of miners' consumption attracted general attention, there has been a somewhat widespread feeling against these lamps, as being responsible for this disease. This opinion, though erroneous, is not of importance, except that it tends to create a feeling that dust prevention is not necessary, and on the part of a ground boss, for instance, might lead to carelessness in this respect.

Carbide gas is poisonous, but there is no more reason for not using a carbide lamp than for not using illuminating gas, which is also poisonous, for cooking or for lighting a house. When carbide lamps fail to work properly underground and require to be opened the gas may escape, but diffusion rapidly takes place, and in the large connected rooms of the Joplin mines the gas could not possibly be in sufficient concentration to cause disease or death. A carbide lamp does not use proportionately as much oxygen as a candle, but

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary diseases among miners in the Joplin district, Missouri, and its relation to rock dust in the mines; a preliminary report: Tech. Paper 105, Bureau of Mines, 1916, p. 34.

a slight difference in this respect is of little importance. Moreover, carbide lamps are in use all over the world, but have never been said to cause pulmonary disease elsewhere than in mines.

COMPRESSOR AIR.

Compressor air is also blamed locally as being a cause of disease and partly responsible for consumption. There are on record accidents that have occurred in various places, owing to the improper use of oil in compressors. The oil became volatilized, and the volatile products were sent through the air lines, causing illness and death to the men at the other end. No such accident has ever occurred in the Joplin district, as far as could be ascertained. During the writer's stay there the men at one mine became ill on one occasion, soon after going to work on the day shift, with suspicion being cast on the compressor air. Investigation placed the blame on powder gas released by shoveling and stirring the dirt piles blasted down on the previous night shift; samples of compressor air were analyzed and the air found to be normal. Various samples at other places showed the oxygen content to be practically always normal.

OVERWORK.

The writer has discussed the subject of overwork among the miners in the Joplin district in Bureau of Mines Technical Paper 105 [a] previously mentioned. As ascertained by Mr. Higgins, the average ore production for all sheet-ground mines is 22 tons per 8-hour shift per shoveler. There is seemingly no prospect of any change in the piecework system, as it suits all concerned. There is one undesirable factor that can be eliminated, probably without a great deal of trouble, and that is the 20-minute dinner period. The State mining law, providing an hour for the noonday meal, should be enforced. Overwork and consequent exhaustion are the great contributing causes of tuberculosis among working people, and in this case there is no good reason why the miners should not have an adequate rest in the middle of their shift.

CHANGE HOUSES.

A notable improvement in regard to change houses has taken place during the past year (1915). Formerly the change house, or, as it was more aptly termed, the "dog house" (Pl. XI, *A*), consisted of a frame shack with a dirt floor, containing a stove, a couple of benches, and occasionally a few lockers. There were no facilities for washing, and garbage, refuse, and dirty and worn-out clothes littered up both the inside and the outside. Miners rarely changed clothes coming off shift, but went home, regardless of the weather, in their dirty and wet working clothes.

---

[a] Lanza, A. J., and Higgins, Edwin, work quoted pp. 38–40.

Now the mines have erected, or are erecting, change houses with concrete floors and concrete or galvanized-iron walls, with plenty of windows and adequate ventilation. (See Pl. XI, *B*.) These change houses have shower baths with hot and cold water, wash basins, and individual lockers for clothes, are ventilated, and are heated by steam pipes. Also most of them have a separate room, with benches and tables, for eating (the men usually come out of the mine to eat).

The new change houses have been received with enthusiasm, and most of the men use them in the manner intended. A recent visit to a change house showed nearly every locker containing clean street clothes as evidence that the men changed when coming off shift.

HOUSING CONDITIONS.

Data on housing conditions were collected in and around Webb City by a series of house-to-house visits. Generally speaking, among miners in Webb City home conditions were fair or good, whereas among those living in the outskirts of town, or on mining land between towns (Pl. XII, *A*), they were bad. Taken all in all, when the wages of the miners in southwestern Missouri are considered, home conditions are far below par as far as sanitation and comfort are concerned. The situation in this respect is remarkable, because it is so needlessly bad. The miners make $3.50 to $5 a day, and even more at times, and they do not migrate to the extent observed in other mining communities. The chief obstacles in the way of improvement are a failure to appreciate better living conditions and, possibly to a lesser extent, the fact that many families live on mining land upon which nothing but temporary shacks can be built. Typical one-room, two-room, and three-room shacks are shown in Plates XIII, *A* and *B*, and XIV, *A*, and miners' homes of the best class are shown in Plate XIV, *B*.

The following tables were compiled from visits to 726 homes and 35 boarding houses. In the total of 761 premises there were 2,348 adults and 1,464 children, as far as could be learned. However, the total number of adults was considerably greater, because the number of boarders, both in boarding houses and in homes, could not be accurately obtained. The number of rooms to the house in 651 premises was as follows:

Number of rooms.	Number of premises.	Number of rooms.	Number of premises.
1	6	7	2
2	107	8	15
3	183	10	4
4	208	12	8
5	67	18	1
6	51	20	1

The houses with seven rooms and over were boarding houses, being two-story frame structures, with the exception of one concrete and one brick building. Practically all the homes were one-story frame buildings, and most of the one, two, and three room homes were "shacks."

The cleanliness in 694 premises was as follows:

Good	217
Fair	318
Bad	159

In the premises rated as "bad" are included most of the two and three room shacks situated outside of town and generally in the most squalid surroundings.

Data regarding the method of heating in 658 premises follow:

Natural-gas stoves	332
Coal stoves	276
Gas and coal	37
Other means	12

Houses in town or on the outskirts are supplied with natural gas, and those situated more remotely have to use coal. Usually the same agent is used for cooking as for heating.

The water supply of a great number of homes is rather unique. Water of good quality is obtained from deep wells and is peddled around the district in water wagons (Pl. XII, *B*) and sold by the barrel wherever there are no water pipes. Wells are scarce, and in the majority of homes the water barrel suffices for cooking and personal needs. Data regarding water supply in 658 premises follow:

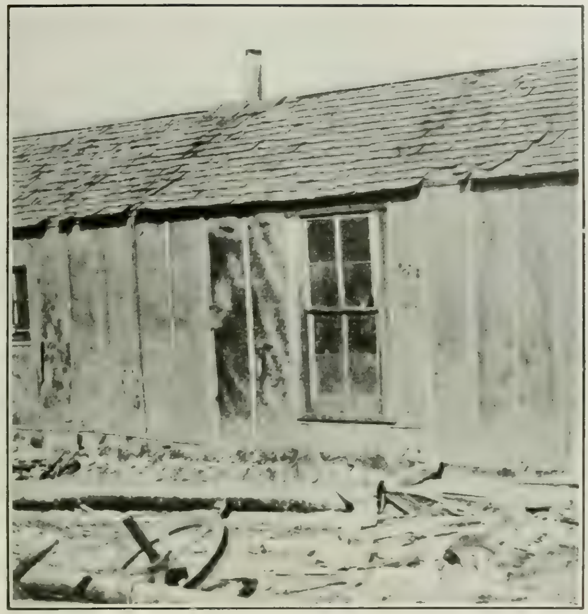
Water obtained from barrel supply	443
City water piped to house	184
Wells	31

The outhouses are wretched, a feature in which southwestern Missouri resembles a great part of the rural communities of the United States. In 680 premises there were 644 insanitary privies, which consisted of the simplest kind of a box structure over a shallow pit dug in the ground. There were sewer connections in 36 premises. In view of the prevalence of filthy privies all over that part of the country, the scarcity of wells is fortunate, and undoubtedly the fact that water is peddled from a pure source is the greatest factor in preventing widespread typhoid fever and other intestinal disorders.

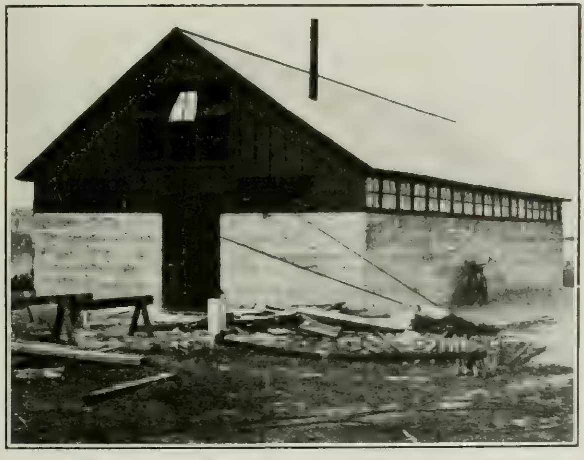
The method of garbage disposal in 610 premises was as follows:

Burned	352
Thrown on the ground around the house	216
Placed in cans and removed	19
Fed to the chickens or other animals	23

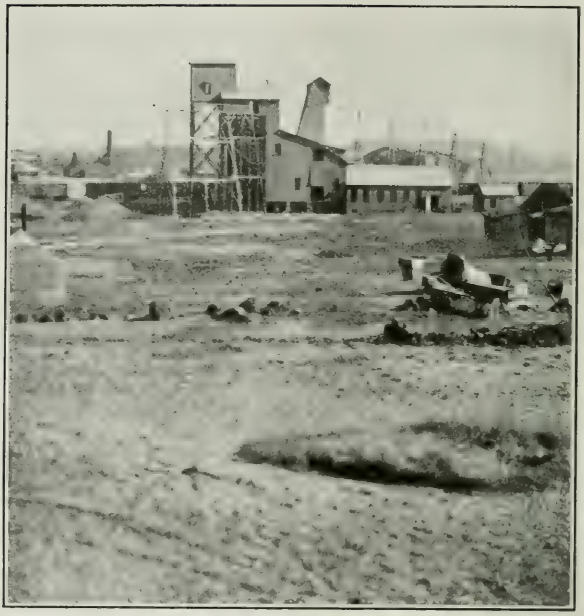
In none of these homes was there a bathtub or bathing facilities other than could be obtained from a pan of water on the kitchen



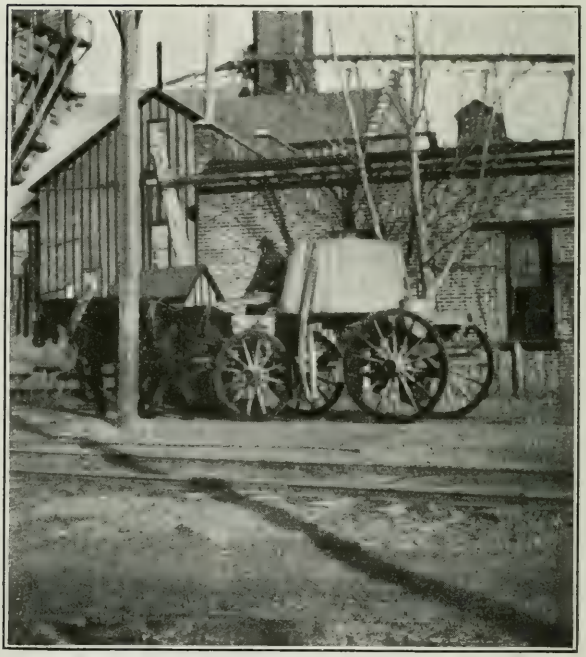
A. TYPE OF CHANGE HOUSE FORMERLY COMMON AND TERMED "DOG HOUSE." DIRT FLOORS, NO LOCKERS, NO BATHING OR WASHING FACILITIES, DIRTY INSIDE AND OUT.



B. CHANGE HOUSE OF NEW TYPE IN COURSE OF CONSTRUCTION. NOTE CONCRETE FOUNDATION AND PROVISION FOR ADEQUATE VENTILATION. CONTAINS VENTILATED LOCKERS, CONCRETE FLOOR, AND SHOWER BATHS WITH HOT AND COLD WATER.



A. SCENE NEAR WEBB CITY, MO. NOTE TENT ON LEFT AND SHACK ON RIGHT, TYPES OF THE FLIMSY STRUCTURE IN WHICH SOME MINERS LIVE, ON MINING LAND.



B. THE WATER WAGON ON ITS ROUNDS.

floor. In 281 premises there were 92 cases of tuberculosis and 120 cases of miners' consumption, representing office cases. In the other places visited information of this kind could not be accurately obtained.

It is impossible to give any figures as to ventilation. Many houses were kept tightly closed all the time, but even then the wind is likely to blow through them. Men suffering from miners' consumption soon find that they can not sleep without an abundance of fresh air, and in the homes of these sufferers doors and windows are usually left open when the weather will permit.

There did not seem to be much evidence of pulmonary tuberculosis among women and children, as a result of the crowded conditions in miners' homes. It is well known, however, that tuberculosis is largely a disease of children, and that in childhood its germs are lodged in the body to become awakened to activity in young adult life, when the stress of living is greatest. The conservation of the children in the Joplin district by taking care of adult consumptives so that they will not become a menace to their families is on a par with rock dust prevention—a matter of vital import. There is a serious need, both in and out of the public schools, of education regarding hygiene.

CARE OF THE SICK.

Recently Jasper County voted bonds to the amount of $100,000 for the erection of a county sanatorium for the care of consumptives. Such an institution is urgently needed, for at the present time there is no local hospital that will take these cases. The State sanatorium for tuberculosis at Mt. Vernon is an admirable institution, but limited by law to incipient or early cases, and consequently few miners are admitted there, as they seldom stop work while still able to get around. Not only for their own comfort, but for the protection of their families and of the community at large, is it necessary that there should be an institution where early cases may learn proper methods of living to combat their disease, and where advanced cases may have a decent and clean place to spend their final days.

There should be, preferably in Webb City, the center of the sheet-ground district, a dispensary where miners could go for physical examination and advice as to lung diseases. There should also be a children's dispensary, with visiting nurses attached, to observe the children in consumptive families, and by remedying the easily corrected defects so common in children, especially nose and throat defects, and by subjecting these children to physical examinations, to minimize the harmful effects of exposure to pulmonary disease. The writer desires to emphasize again that while miners' consumption is not infectious nor contagious, yet one can never know when a tuberculous infection may occur, and consequently in all public-

health work miners' consumption should be treated with the same caution as is pulmonary tuberculosis.

It is to be hoped that local hospital and sanitary organizations will be able, in the near future, to organize a dispensary for both adults and children, with a visiting-nurse service. At the present time the Jasper County antituberculosis society and the Metropolitan Life Insurance Co. both maintain efficient visiting nurses, but it is probable that these different lines of endeavor, together with the cooperation of the miners, could be combined in connection with a dispensary service to the benefit of all concerned.[a]

The desired treatment of miners' consumption is purely hygienic—rest, fresh air, and good food. No medicine can restore those parts of the lung destroyed or damaged by rock dust. As with the great bulk of our tuberculosis sufferers, it is the financial inability to take sufficient rest and to change the occupation that is the most formidable obstacle to recovery.

Early cases of miners' consumption recover, as a rule, on removal from the cause, the inhalation of stone dust. Later cases may recover, but once the lung is seriously injured, not only is the breathing capacity permanently impaired, but a tuberculous infection is almost inevitable, and when that takes place in the already damaged lung the prospects for recovery are slight.

The writer has seen three or four sufferers from advanced miners' consumption who are seemingly recovering, after resting from all work for a number of months. They all look well and feel well, and two of them now do light work, although they can not do any hard work because of shortness of breath; the significant point is that they are improving. These cases are so exceptional that they stand out in a crowd of over 700. Still the fact remains that with a prolonged rest sufferers from miners' consumption may recover.

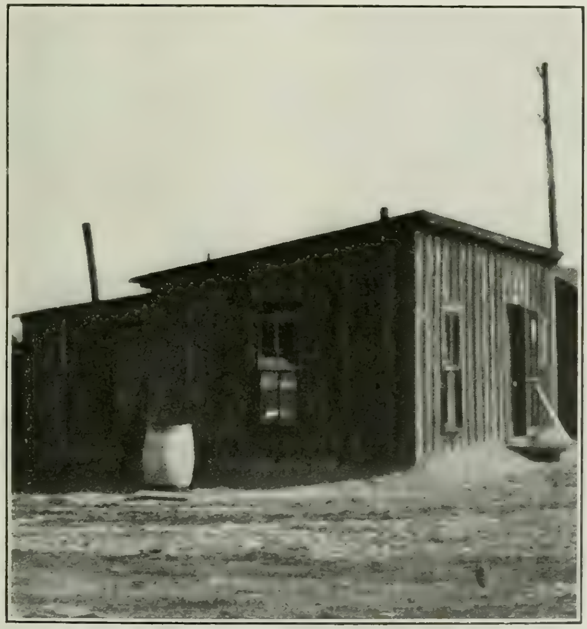
The question may arise as to the advisability of sending patients in the early stages of miners' consumption to a tuberculosis sanitarium for rest. As far as the patient is concerned, there is no sound objection to such a proceeding. Tuberculous infection is often a matter of doubt in these cases, but the patients will be in less danger in a properly regulated institution, where care is taken to prevent the spread of infection, than they would be at large.

SICKNESS INSURANCE.

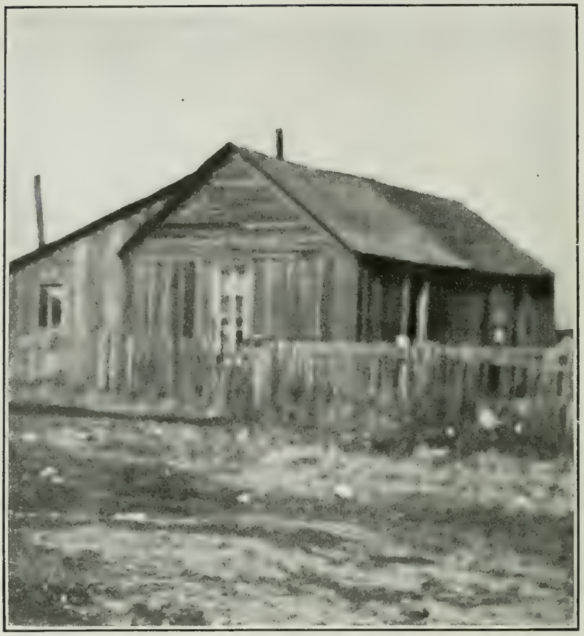
Although sickness insurance has not been established on a firm basis in this country as yet, the experience of foreign countries, where this system has been eminently successful, indicates that

[a] Since this report was drafted, such a dispensary for adults and children has been opened and is being maintained in Webb City through the cooperation of the Jasper County antituberculosis society of the southwest Missouri mine safety and sanitation association.

A. ONE-ROOM SHACK, OCCUPIED BY TWO PEOPLE. MINER HAS MINERS' CONSUMPTION.



B. TWO-ROOM SHACK, OCCUPIED BY TWO ADULTS AND TWO CHILDREN. ONE OF ADULTS HAS MINERS' CONSUMPTION. NOTE WATER BARREL.



A. THREE-ROOM BOARDING HOUSE; TWO ADULTS AND THREE CHILDREN IN FAMILY AND SIX BOARDERS. ONE INMATE HAS MINERS' CONSUMPTION AND ONE CHILD IS TUBERCULOUS.

B. MINERS' HOMES OF THE BEST CLASS.

sickness insurance must finally be instituted in southwestern Missouri if adequate relief from the burden of lung diseases is ever to be obtained.

It is not within the scope of this report to outline any scheme of sickness insurance with its somewhat complex details. It is desired to call the matter to the attention of the State department of health and charities, county, municipal, and mine-owners' organizations, and others interested, in the hope that by far-sighted cooperation the establishment of such a system may be undertaken. In the event that State assistance can not be procured, it may be possible to arrange among employers and employees a beneficial organization of the type that has proved so successful in some of the big mining and manufacturing districts in this country.

Workmen's compensation laws are already definitely established, and will probably be in force in Missouri before very long. The loss of time and of life from industrial sickness is far greater than from industrial accidents, and is quite as amenable to prevention and remedial legislation.[a]

CONCLUSIONS.

1. There is much pulmonary disease due to rock dust among the miners of the Joplin district, affecting probably as high as 30 per cent of sheet-ground miners.
2. The amelioration of dust-producing conditions is progressing at a reasonable rate.
3. Living conditions are generally poor, and often needlessly bad.
4. Although miners' consumption and tuberculosis of the lungs are entirely different diseases, as regards the public health no distinction should be made as to precautions against spread of infection.
5. The prevention of the spread of tuberculous infection, especially to children in the homes of consumptives, is of paramount importance.
6. The combination of hard work with a short dinner period is injurious and unnecessary.

RECOMMENDATIONS.

Instructions should be given from time to time, especially to new men, regarding the harmfulness of rock dust and regarding methods for its prevention. Educational leaflets should be distributed by the State bureau of mines, or local sanitary societies.[b]

There should be established a dispensary, or similar organization, to afford the miners the opportunity for physical examinations.

[a] Warren, B. S., Sickness insurance, its relation to public health and common welfare: Public Health Report, No. 250, U. S. Public Health Service, January, 1915.

[b] The State mine inspectors do as much educational work as their duties permit.

There should also be medical inspection of schools and a visiting-nurse service, especially for the children of consumptive parents.

Continued care and vigilance should be maintained to abate squibbing and bowlder popping, and especially should attention be directed to lessening these abuses during the night shift.

An effort should be made, through cooperation of all concerned, to prescribe a maximum daily tonnage for shovelers.

It has been the experience of other communities and other countries that workmen's compensation laws and sickness insurance offer practical and equitable relief from the effects of various industrial conditions that are, in themselves, not entirely remediable. It is the opinion of the writer that such a system will eventually prevail in the Joplin district, and must prevail before present abuses will be reduced to a satisfactory minimum.

HISTORICAL REVIEW OF SILICOSIS.

By GEORGE S. RICE.

Silicosis, sometimes known as miners' consumption, is a specific occupational disease. It was seemingly known to the ancients, as is clearly shown in a paper by De Fenton,[a] read before the Chemical, Metallurgical and Mining Societies of South Africa, in May, 1916.

Hippocrates,[b] in his "Epidemics," speaks of the metal digger who breathes with difficulty, and is of a pale, wan complexion.

Pliny the Elder,[c] in his "Natural history," speaks of the use of respirators to avoid dust inhalation, as follows:

> Those employed in the works preparing vermilion (?) cover their face with loose bladder skins that they may not inhale the pernicious powder. and yet may see through the skin.

Loehniss,[d] in a book on mines and mine workers, published in 1690, says:

> The dust and stones fall upon the lungs, so that the men have lung disease, breathe with difficulty, and at last take consumption.

Diembroek[e] found in men's lungs such heaps of sand that in running the knife through the pulmonary vesicles he thought he was cutting some sandy body. This, by the way, was the experience of De Fenton, who, in the early days of the Rand, chipped many a razor blade while endeavoring to cut sections from dust-congested lungs.

Agricola (1494 to 1555), in his most famous work, "De re metallica," published in 1556, the year following his death, gives a considerable description of miners' diseases of the respiratory organs and their causes, a splendid translation of which, by Hoover and Hoover,[f] appeared in 1912. These diseases, as described by Agricola, De Fenton classified under two heads, as follows: (1) Those diseases which arise from stagnant air, or want of ventilation; and (2) those

---

[a] De Fenton, J., On some diseases of the respiratory organs incidental to miners, as portrayed by Dr. Agricola, in A. D. 1550: Jour. Chem., Met., and Min. Soc. South Africa, May, 1916, pp. 223–227.

[b] Littré, E., Oeuvres complètes d'Hippocrate, avec le texte grec en regard, vol. 5, 1846, p. 147.

[c] Plinius Secundus, C., Historiae naturalis, lib. 33, sec. 11.

[d] Loehniss, G. E., Bericht von Bergwerchen, 1690, p. 56.

[e] See Ramazzini, B., A treatise of the diseases of tradesmen, translated by Dr. James, London, 1705, p. 163.

[f] Hoover, H. C., and Hoover, L. H., Georgius Agricola, De re metallica, London, 1912, 640 pp.

which are caused by the corrosive action of dust on the lungs of the miner. He finds four references under the first class, which he translates as follows:

Because the miners are liable to be killed, (*a*) sometimes by the pestilential air which they take in by breathing; (*b*) sometimes stagnant air, remaining either in a shaft or in a tunnel, produces a difficulty in breathing. The remedy for this evil are the ventilating machines.

(*c*) If a shaft be very deep, and no tunnel or drive from another shaft reaches to it; or, if a tunnel be of great length, and no shaft connects with it, then the air does not replenish itself. In such a case it weighs heavily upon the miners, and they breathe with difficulty. Sometimes, indeed, they are suffocated, and burning lights are extinguished. And so one needs those machines which both Greek and Latin call "breathing," though they give forth no sound: for they enable the miners both to breathe easily and to complete the work in hand.

(*d*) Air, indeed, remains stagnant both in tunnels and in shafts. This will occur in a deep shaft if it be by itself, i. e., if no tunnel connects with it and it is unconnected with any other shaft by a drive. * * * For this reason the vapors become heavy and like mist, and smell of moldiness like a vault, or some underground cellar which has been entirely closed for many years. Wherefore the miners are unable to continue work in these places for long (even though the digging may abound in gold and silver), or if they do they are unable to breathe freely, and suffer from headaches. This happens the more often if they work in such places many together and employ many lamps, which then supply them with but a feeble light. For the vapors which both men and lamps give out produce in their turn vapors which make the previous atmosphere fouler still.

Regarding the second class of diseases De Fenton extracts as follows:

On the other hand, some diggings are so dry that they are entirely deficient in water, and this dryness produces even greater harm for the workmen; for the dust which is stirred up and put in motion by digging, penetrating right into the windpipe and lungs, engenders a difficulty in breathing and the illness which the Greeks call asthma. And if dust happens to have corrosive powers it eats away the lungs and engenders consumption in the body. Hence, in the mines of the Carpathian Mountains one finds women who have been married to seven husbands, all of whom this terrible disease has carried away by a premature death.

The Hoover translation of this reference is as follows:

The critics say, further, that mining is a perilous occupation to pursue, because the miners are sometimes killed by the pestilential air which they breathe; sometimes their lungs rot away; sometimes the men perish by being crushed in masses of rock; sometimes, falling from ladders into the shafts, they break their arms, legs, or necks; and it is added that there is no compensation which should be thought great enough to equalize the extreme dangers to safety and life.

De Fenton criticizes the Hoover translation as being too general, whereas his own translation is more literal, and he states, "Agricola's phrasing is most pregnant, and pithily and accurately conveys to our mind the nature of the disease intended to be expressed. Remembering that the writer was a medical man with some 29 years' experience as a mine doctor, it behooves us to pay the greatest attention to the text."

In trades other than mining the danger of breathing certain kinds of mineral dusts has been indicated. Oliver,[a] in "Diseases of occupation," states:

> As far back as the days of Ramazzini (1670) the lung troubles of the potter had been recognized and described. With the terms "potters' rot" and "potters' asthma" the public are quite familiar. It is this liability to lung disease on the one hand and to lead poisoning on the other that has placed pottery manufacture high up the list of dangerous trades.
>
> In firing china the articles are separated by means of ground flint, which is used over and over again. The particles of flint are sharp and angular and when breathed cause irritation and coughing.

Stonemasons, it has long been known, are subject to lung diseases. The French slate workers are exposed to breathing large amounts of schistose dust. Oliver[b] says:

> Dr. Hamaide, of Fumay, who knows the slate miners well, says that they begin to suffer from bronchitis between the ages of 35 and 40 years, and that once this becomes fixed and is followed by structural alterations of the lungs and bronchi, the malady proves fatal in 5 to 10 years. The mean duration of the life of the Fumay slate miner is 48 years. He has seen men who are the subjects of slate miners' phthisis expectorate fragments of hard stony material like schist, accompanied by profuse bleeding from the lungs.

It is thus seen that it is not alone underground workers who are subject to the malady, and that the disease is caused by dust rather than impure air; although the latter may in some cases be a factor in intensifying the trouble. Statistics in various countries show that coal miners and iron-ore miners are not subject to pulmonary troubles more than the average of men in the general occupations. In fact, the mortality among coal miners from pulmonary tuberculosis and pneumonia is less, so that it is thought that there is some protective influence exercised by coal dust. The fresh coal dust is sterile, and the particles do not irritate the lungs, in spite of the fact that the lung tissue of workers may be blackened by coal dust. Pennsylvania anthracite dust, however, although not causing miners' consumption, does appear to produce asthma, possibly owing to the hardness and sharp edges of the particles.

As regards the relation of dust to lung diseases Oliver[c] says:

> It was left to Peacock to establish the relationship between dust and lung diseases by demonstrating both chemically and microscopically the identity of the dust found in the lungs after death with that of the atmosphere in which the patient had worked. In the various pneumokonioses, or lung diseases caused by the inhalation of dust, the lesions in the lungs are, practically speaking, identical, quite irrespective of the nature of the dust. The lung substance, instead of remaining soft and spongy, becomes converted into a hard, unyielding substance, composed for the greater part of fibrous tissue. Thus structurally altered, the lungs are unable to discharge their function as organs of aeration.

---

[a] Oliver, Thomas, Diseases of occupation, London, 1908, p. 307.

[b] Oliver, Thomas, work quoted, p. 304.

[c] Oliver, Thomas, work quoted, p. 280.

That it was the character of the dust which led to excessive pulmonary diseases among metal miners was early recognized in Great Britain. The statistics of the deaths from lung diseases and other causes in 1849–53 show that although the coal miners of Staffordshire, South Wales, and Durham had a lower annual death rate than the average of all the males of England and Wales, the average death rate of the Cornish miners mining tin and copper, after the miners had reached the age of 35, was much higher than that of the average occupied male. Between the ages of 35 and 45, the number of deaths per 1,000 was 8.5 for miners and 5.3 for all occupied males; between the ages of 45 and 55 the respective rates were 24.3 and 6.8; and between 55 and 65 were 44.5 and 9.6.

In 1901 Drs. Robertshaw and Leggi investigated the cause of excessive death rate from dust inhalation among ganister miners. A royal commission was appointed in 1902 consisting of Dr. J. S. Haldane, J. S. Martin, and R. A. Thomas, to make an inquiry into the health of Cornish miners. Its report [a] showed the prevalence of lung disease among these miners as indicated above.

From an official standpoint the matter then rested in Great Britain until 1914 when a report was made by the Royal Commission on Metalliferous Mines. This report deals with miners' phthisis.

This commission quotes the results of experiments by Prof. Beattie at Sheffield University on the relative importance of certain mineral dust as a possible cause of fibrosis of the lungs. He found that the dust of some minerals, such as coal, clay, and cement, were not shown by experiment to be injurious, but other dusts, such as silica, quartz, flint, sandstone, carborundum, and emery were, and that fine crystalline silica was especially injurious. The commission agreed with these findings, but in the course of its report stated that the cause of miners' phthisis was the inhalation of dust of crystalline silica upon which is superimposed tubercular infection, and that fibrosis is not necessarily dangerous to life.

SILICOSIS IN SOUTH AFRICAN GOLD MINES.

The enormous development of gold mining on the Rand was accompanied by great mortality among the natives as well as the Europeans who worked in the mines. The vein rock is a conglomerate of the hardest kind, difficult to drill and still more difficult to blast. Unless extraordinary precautions are taken, enormous amounts of dry dust are produced, and if the air is kept agitated the atmosphere is charged with fine siliceous dust. The matter became so serious that it was brought to public attention shortly after the close of the Boer war.

[a] Haldane, J. S., Martin, J. S., and Thomas, R. A., Report to the secretary of state for the home department on the health of Cornish miners, 1904.

As Oliver[a] states, "a few years previously young miners in the bloom of health had left their northern homes for South African gold fields, and after working there for four to six years returned to Northumberland and elsewhere broken in health."

In consequence, in 1902 the British Government appointed a commission to inquire into and report on the subject of phthisis in the mines of the Transvaal and to make recommendations as to preventive and curative measures. The report was published in 1903.

In the Rand mines, the great depth and consequent high temperatures, with chilling of the body when men were raised to the surface, according to Oliver, were responsible for bronchial catarrh and bronchitis, which intensified the condition produced by inhalation of dust. It was noted on the Rand that miners' phthisis started without previous outward symptoms, but once the disease gained a hold conditions might cause marked physical symptoms, one of the first being shortness of breath. The victim does not feel ill until the disease is far advanced, unlike tuberculosis and phthisis. Oliver[b] further comments:

Loss of flesh and strength is so gradual that the miner continues to follow his calling, for the cough is slight and there is little or no expectoration. By degrees a sense of weakness impresses itself upon the patient, but it is the shortness of breath that obliges him to give up work. When the disease is fully established, it is observed, in addition to the dullness in the chest on percussion, that the breath sounds are coarse and tubular, but in the absence of accompanying bronchial catarrh moist râles are not usually heard. There is often pain in the chest, owing to the presence of a limited pleurisy over the patch of fibrotic lung, which explains the adhesions that are found after death binding the lungs to the chest wall internally. There is, as a rule, neither the rise of temperature nor the evening sweating which are present in tuberculosis phthisis, and "blood spitting" is an extremely rare event. So markedly absent is expectoration in uncomplicated cases that it is difficult to obtain sputum for bacteriological examination. In the early part of the illness, and sometimes throughout the whole of it, as in some of my own patients, the expectoration is free from tubercle bacilli. In other instances, toward the end of life tubercle bacilli are found in the sputum. This circumstance, the physical signs and symptoms, as well as the course of the disease, point to Rand miners' phthisis as being in the first instance a purely local affection of the lungs, the result of irritation by dust, and without tubercle. When the disease has become tuberculous, it is in consequence of superadded infection.

The report of the first commission (1902–3) showed that the disease was common among rock-drill men, and the conclusion was that dust inhalation was the cause of the disease. Some of the commission's important findings are given in the following extracts:

Miners' phthisis is not peculiar to machine miners, for although it is most typically and commonly seen in them, it frequently develops also in course of time amongst miners who have never used rock drills at all. Most cases of this sort, however, have been mining for long periods, e. g., over 30 years, and it may be taken that the ordinary miner has a considerable advantage in length of life over the rock-drill miner.

[a] Oliver, Thomas, work quoted, p. 279.
[b] Same, p. 281.

The disease undoubtedly falls most heavily on rock-drill miners. Out of the living rock-drill miners whose cases we have investigated, the majority of those who have been working rock drills for over 5 years were found to be suffering more or less from chest symptoms; the average time that those who were admittedly so affected had been employed on rock-drill work was from 7 to 9 years (ranging from 6 to 15) out of a mining life of 18 years. They died at the average age of 35.

It is true that men may be found who have worked for 10 years or more with rock drills and whose health is not perceptibly impaired; on the other hand others have become affected under the average time. Probably in this respect a great deal depends on the class and type of mining engaged in, and its locality. Wet mines have a much better reputation than dry mines. The quartzite of the gold-bearing beds of the Witwatersrand is admittedly very hard, and the mines are practically all "dry." There is also no doubt that persons who inherit chest weakness are more liable to be attacked by disease of this nature; but while this fact may explain some individual variations, it does not explain the enormous incidence of chest disease on miners as a class. The same observation may be made with regard to personal habits of intemperance and mode of living.

All the statistical evidence goes to show that developing, i. e., "raising" and "driving," is more dangerous to health than working in stopes. The most striking case in point which the statistics furnish is that of two brothers, who worked rock drills for four years only, doing nothing but "raising" all the time, and who died thereafter of chest disease at the age of 28 and 29, respectively.

RESULTS OF CLINICAL EXAMINATION.

Clinical investigation and examination show that the disease is an extremely insidious one, of very gradual development, having in its earlier stage little or no obvious effect on the general health, so that by the time the working efficiency of the miner becomes seriously impaired the disease is, as a rule, already well advanced.

The usual symptoms in a typical case are in the earlier stages recurrent and obstinate bronchial "colds" which may attract little attention, for the patient being for a long time quite able to work is apt to regard his earlier symptoms as of little moment. Gradually as the disease progresses shortness of breath on exertion, cough, and spit, a more frequent liability to contract colds and a greater difficulty in throwing them off, and sometimes flitting pleuratic pains, are the symptoms which usually first attract serious notice.

Gradual loss of weight and strength and more urgent breathlessness, which may be of an asthmatic type, follow, as an increasing area of breathing space becomes disabled. Expectoration may or may not be a prominent symptom; hemoptysis is exceptional and when present is usually slight; night sweats are not as a rule noticeable, and pyrexia may be altogether absent throughout. Three of the characteristic signs of tubercular phthisis are thus frequently absent.

Finally toward the end the patient rapidly loses ground in all directions.

The most striking feature brought out by the physical examination in a typical case is the diminished expansion of the chest, which in many cases is very striking, and is accompanied by rigidity of the chest wall, so that breathing becomes mainly abdominal. Percussion and auscultation often give very indefinite results owing to the diffuse nature of the disease. The disease is bilateral, but one lung is frequently affected to a greater degree than the other.

It is not common to find the typical physical signs of tubercular phthisis present, and this observation, together with the confirmatory fact that out of a series of over 30 sputa from cases of disease of the lung of miners examined by a member of your committee only 2 or 3 were found to contain tubercle bacilli, leads us to conclude that, while in some cases a true tubercular phthisis may coexist or may be superadded, the

conjunction is only seen in a minority of cases.[a] * * * The disease is primarily a local one, and is at first confined to the respiratory organs; secondary disorders of the heart, liver, stomach, and kidneys are late accompaniments. The heart is not as a rule dilated, but the pulse rate may be accelerated.

In the more chronic forms, seen perhaps more typically in the miners of many years' standing, who as a rule are not rock-drill workers, chronic bronchitic and asthmatic symptoms are perhaps more prominent, and in them dilatation of the heart and accelerated pulse rate are more common.

We may therefore perhaps usefully distinguish from a clinical standpoint three types of "miners' phthisis."

(1) The pure fibroid nontubercular type, the commonest and most characteristic form of the disease.

(2) The mixed fibroid and tubercular type, where the two processes coexist.

(3) The very chronic type seen in miners of many years' standing, where the fibroid change in the lungs, although more chronic is less extreme, and where secondary changes in the heart and kidneys are more prominent.

In speaking of the Transvaal investigation, Oliver[b] says:

In mining it is not the coarse particles but the fine, impalpable dust which is the source of danger, and which, in consequence of the arduous nature of the work in an overheated atmosphere, is drawn by the miner into the recesses of his lungs owing to deeper breaths he is obliged to take.

The amount of dust raised varies from 0.083 to 0.185 grain per cubic foot of air, so that a miner breathing his average 21 cubic feet of air per hour would run the risk of inhaling about 2.38 grains of fine dust per hour; hence the large quantity of silica found on chemical analysis of the lungs of gold miners after death, amounting frequently to 24.4 per cent of the total weight of the organs. Of 1,377 rock-drill miners employed in the Witwatersrand mines prior to the South African campaign, 225, or 16.34 per cent, died during the 2½ years immediately preceding the war.

This commission of 1902–3 seemed inclined to the view that gaseous impurities in the mine air predispose miners to miners' phthisis; the impurities arise from fumes of explosives. Its report disclosed a most serious situation regarding the presence of phthisis.

In 1907 another Rand commission was appointed to report on the working of the mines, work, and machinery regulations. This commission also gave much attention to miners' phthisis. Its report, published in 1910, sets, for the first time in South Africa, a definite standard of metal mine ventilation, based on a maximum allowable percentage of impurity as determined by chemical analysis of samples.

In 1911 a commission was appointed by the Union of South Africa, known as "The Miners' Phthisis Commission," to inquire into: (*a*) The extent to which miners' phthisis and pulmonary tuberculosis are prevalent among persons employed in certain mines; (*b*) the degree to which and the stage at which any person employed in such mines becomes incapacited by miners' phthisis and pulmonary tuberculosis from performing work; (*c*) the number of men who may

[a] In more recent reports the South African commission has changed its views on this question.
[b] Oliver, Thomas, Diseases of occupation, London, 1907, p. 282.

be expected to become incapacitated annually; (*d*) the probable life of a sufferer after having become so incapacitated; (*e*) the provisions for compensation or insurance against phthisis.

The findings of this commission, published in 1912, covered an examination of 3,181 miners, of whom 1,009 were afflicted with phthisis.

Another commission, the Miners' Phthisis Prevention Committee, was appointed in 1912 by the Union of South Africa, "to inquire into by experimental or other investigations and to report from time to time upon the improvement of methods for the prevention of miners' phthisis in the Witwatersrand Gold Mine, and to advise upon the introduction of a systematic and uniform policy and the amendments to the mining regulations which may be necessary for combating the disease."

This commission issued a preliminary report in 1912, an interim report in 1913, a special report dealing with the percentage of injurious particles in mine dust and on the counting of the particles of dust in air, in 1915, and a general report in 1916.

One of the first matters taken up was sampling air for dust contents, and the commission continued this work three and one-half years, taking a total of 2,809 such samples in the mines and on the surface. Samples were weighed and when it was considered desirable the number of particles was estimated. Wet and dry bulb readings were taken in conjunction with the sampling, and 100 samples of mine air were taken to determine percentages of deleterious gases present.

The Medical Commission in a report issued in 1912,[a] gave the following definition of the disease:

(1) Miners' phthisis is a chronic disease of the lungs, characterized by progressive fibroid changes in the lung tissue and pleura, and accompanied by chronic catarrhal processes in the air cells and respiratory passages. The disease is thus primarily a fibrosis of the lung, and the essential factor in producing this condition is the more or less continuous inhalation over long periods of fine rock dust. All true cases of miners' phthisis are thus primarily cases of silicosis; silicosis is the feature common to them all.

(2) In the latter states tuberculosis becomes commonly or invariably superimposed upon this condition, and the type of the disease becomes that of a tuberculous infection in a fibroid lung.

The report suggests that repeated exposure to the fumes of explosives in small quantities is a subsidiary factor in developing the disease. The definition states the important fact that ordinarily miners' phthisis does not run its course and terminate in death as the result of a single pathological process, but begins with silicosis and ends in an infective process.

---

[a] Report of a Commission on Miners' Phthisis and Pulmonary Tuberculosis, Pretoria, 1912, p. 10.

A great majority of the cases in the early stage of the disease are those of silicosis uncomplicated by tuberculosis, and if the sufferer leaves underground work he may remain free from tuberculosis. On the other hand, if underground work is continued tuberculosis will nearly always follow. The following description of the structure of the lungs is important for the layman to remember in studying the effects of the disease.[a]

In order to reach the lungs the air which we breathe has to pass through the "air passages." First, it is conducted through the mouth or nose, the back of the throat, and the larynx, to the windpipe. The windpipe finally divides just above the heart into two large tubes, the right and left bronchi, which conduct the air respectively into the right and left lung. Each main "bronchus" immediately gives off branches, and these again smaller and still smaller branches, by which means the air is conducted to every part of the lung. Corresponding to this tree-like branching of the air tubes is the similar branching system of the arteries, which convey throughout the lung the blood which comes to it to be purified in breathing, and of the veins, which carry back to the heart the purified blood. These three branching systems, bronchi, arteries, and veins, run together throughout the lung.

Each minute tubular end branch or twig of the bronchial tree (called a "bronchiole") ends by dividing into several very small passages, round each of which is disposed a cluster of "air vesicles" or "alveoli." Each "air vesicle" is a roughly hemispherical tiny sac, the inner side of which is open to the air-containing passage in which the minute bronchus ends. Its outer side is covered by a close network of capillary blood-vessels. The wall of the "air vesicle" is extremely thin, in order to permit the interchange of gases between the blood and the air which goes on in breathing. The gases must pass through the thin walls of the air vesicle to reach the blood, and vice versa. Similarly, in order to penetrate into the lung, fine dust or pigmented matter must first pass through the fine walls of these little sacs.

The group of clusters of air vesicles, into which any one of the terminal ramifications of the bronchial tree leads, is called a "lobule," and there are in either lung thousands of such lobules, separated off from each other by fine partitions, derived from the supporting fibrous framework which runs throughout the lung.

The surface of each lung is covered by a smooth membrane, called the "pleura" or "pleural membrane," and this membrane is continuous at the "root" of the lung with a similar membrane lining the inner surface of the chest wall. Between the pleural membrane which covers the lung and that which lines the chest wall, a thin layer of fluid is normally interposed, an arrangement which facilitates the free movement of the lungs in breathing. When pleurisy (or inflammation of the pleural membranes) occurs, the two layers may become adherent, and the movement of the lung is then correspondingly hampered.

The air passages throughout are lined by a membrane which is kept moist by the secretion of "mucus" from its surface. This moist membrane tends to arrest dust or infective particles entering with the inspired air.

The interior of the nose also is so constructed that the organ under ordinary circumstances acts as an efficient dust arrester.

Further, the lining membrane of the lower air passages, namely, the windpipe, bronchi, and bronchial tubes, down to the very smallest of these, is provided with a multitude of excessively minute whiplike processes, called "cilia." The "cilia" are always in motion and maintain an outward movement of the mucus or "phlegm" away from the smallest tubes, and towards the windpipe and larynx. When the mucus

[a] General Report of the Miners' Phthisis Prevention Committee, Pretoria, 1916, pp. 10-12.

reaches the latter, its presence irritates the very sensitive surface of the larynx and induces a cough, by which the phlegm is expelled into the mouth.

These details are important, because the air passages furnish, in the manner described, a protective mechanism against the entry of foreign particles, such as dust, into the air vesicles.

Very much of any dust which is inhaled is entangled on the moist surfaces of the nose and throat, and if it is not present in overwhelming amounts, the portion of it which reaches the "bronchial tubes" is gradually worked upwards again in the phlegm and expectorated.

But when dust is continually inhaled in large quantities, this protective mechanism, adequate as it is under ordinary conditions, fails to completely fulfill its function. Many, especially of the finer particles, pass the protective barriers and gain access to the air vesicles.

The presence of irritant mineral particles in the bronchial tubes sets up a process of inflammation or "catarrh," which, by damaging the lining membrane, impairs the protective action of the "cilia," reduces the efficiency of the whole protective mechanism, and accelerates its breakdown. Similar catarrhal changes take place in the air vesicles also, when dust gains entry to them.

It is most important, therefore, for those employed underground to keep the protective mechanism, with which nature has provided them, in a state of efficiency. Exercise in the open air after working hours is to be strongly encouraged. Whether such exercise is taken or not, the systematic practice of simple breathing movements, which anyone can readily learn, will also help greatly to maintain the normal power of chest expansion, stimulate the circulation in the lungs, and promote the healthy activity of the whole breathing mechanism. Dust will thus be got rid of which otherwise would have remained behind to do further damage.

A regular annual holiday away from the inimical influences of underground work is also a very important preventive measure.

When dust is inhaled day by day in large quantity the protective mechanism provided by the air passages proves, as has been said, inadequate. Many of the very fine particles of the inhaled dust are carried, not only to the bronichal tubes, but to the air vesicles or alveoli, in both of which situations they set up catarrhal changes. This element of "catarrh" is one factor in miners' phthisis, and may from time to time be rendered acute by recurring "colds" of infective origin. Exposure to even minute quantities of nitrous fumes will also, when it occurs, provoke and maintain catarrh, and thus further weaken the resisting power of the lung against attack by dust. The catarrhal change in the alveoli is characterized by multiplication and shedding of the cells which line the walls of these tiny sacs. These cells readily take up dust.

The next step is that, ultimately, in many parts of the lung, a proportion of the very fine silicious particles gains entrance through the walls of the air vesicles to the surrounding connective tissue of the framework of the lung, chiefly through the agency of the shed alveolar cells, which act as carriers. Once in this situation the dust particles are carried along the lymphatic channels, and some lodge at various points in the course of the latter. At these points their irritant properties produce a slow reactive inflammatory change, characterized by the production of new fibrous tissue. This new fibrous formation is at first found around the smallest ramifications of the air tubes and blood vessels of the lung, principally in a finely nodular form, but it also leads to thickening of the fibrous framework of the organ and frequently of the pleural membrane which invests the lung. The air vesicles in the neighborhood of the areas of fibrous formation, and sometimes more generally, are observed to be in a state of "catarrh."

The new fibrous tissue appears first in small discrete areas. These gradually become more numerous throughout the lung and at the same time increase in size and extent

at each point affected, so that they ultimately tend to coalesce with similar neighboring areas.

In time this fibroid change leads to a considerable amount of obliteration of the fine air tubes and blood vessels (or portions of them) and of air vesicles throughout the lung. The result of this is to reduce the reserve of air capacity, available in breathing, which exists in the normal lung. The thickening which takes place in the fibrous framework, and very frequently in the pleural membrane, aggravates this condition and impairs the capacity of the organ to expand during breathing. The silicotic process may, in time, lead to the formation of more or less extensive areas of dense fibroid consolidation, which render the portions of the lung so affected practically airless. The cardinal symptom of silicosis, shortness of breath on exertion, thus becomes readily intelligible. First, there is an increasing effort in breathing deeply; later on there is actual incapacity to do so.

A lung in a condition of silicosis is, as has been said, liable to intercurrent ineffective invasions throughout its course. Thus, attacks of bronchial or pulmonary catarrh or localized pleurisy are not uncommon, and are a factor of aggravation in the disease. Pneumonia may also occur as a complication at any stage and may cause death. If recovery takes place, this disease is characteristically slow to clear up in a silicotic lung.

But the most serious invasion to which such a lung is liable is tuberculosis. When tuberculosis invades a silicotic lung, destructive and obliterative changes become much more marked. More or less extensive areas of consolidation, which is frequently of a very dense fibroid character, result. The extensive areas of dense fibroid consolidation which are characteristic of cases of advanced miners' phthisis appear, indeed, most commonly to arise in this way, and to have a mixed silicotic and infective origin. In addition to the changes in the lung, the ordinary constitutional effects of the infection become apparent. The disease alters its type, and the characteristic symptoms of a simple silicosis are aggravated by, and to a large extent merged in, those of an acute or chronic pulmonary tuberculosis.

The Medical Commission stated that, as a result of the examination of 3,136 underground workers, 26 per cent of the general body of miners at work were found to show definite signs of silicosis, while a further 5.5 per cent were classed as probable but not definite cases. The disease especially affected the rock-drill miners, and successively in the order of risk, trammers, hammermen, and timbermen, but no group of underground workers were found to be free from serious risk of attack. Even the supervisory staff was not exempt. The Medical Commission advocated a strict system of selection of recruits for underground work. A man best suited for underground work was "one of good, sound physique and with a good reserve of respiratory capacity." They considered that it was not wise to accept a man over 45 years of age, because of a tendency to increasing reduction of the expansile power in the chest walls and a proneness to bronchitis and emphysema.

All having sign of tuberculosis taint should be rigidly excluded.

The risk of conveyance of tuberculosis from infected to healthy persons underground, the commission considered, is by no means negligible. Out of 205 specimens of sputum collected underground

31222°—17——7

15.2 per cent contained the tubercle bacillus. Infection is more likely to arise from contamination of hands and subsequent ingestion. All water for sprays, as well as drinking, should be pure. There should be disinfection of ladder and traveling ways, also of change houses and living rooms.

Dr. McCrae found that dust from lungs of deceased miners consisted principally of extremely minute particles, none larger than 12 microns in diameter, and the majority less than 1 or 2 microns.[a]

In a miner's lungs containing 20 grams of silica the total number of particles, if they averaged 2 microns in diameter, would be six million million.

Character of dust found in mines on the Rand.

Constituents.	Original ore.	Dust from blasting.
Silica (SiO_2)	87.4	69.8
Alumina (Al_2O_3)	9.8	22.5
Iron (Fe)	1.75	4.5
Basic oxides (CaO, MgO, FeO_2)	Traces.	3.2
Sulphur (S)	1.1	(a)

a Sulphur drawn off in heating dust.

The mining operations which result in dust being formed and projected into air were divided by the commission into four classes: Blasting, drilling, transport, breaking and crushing rock.

The first two are the important causes underground. The effect of blasting was tested at one time by systematic sampling of the main return air near the exhaust fan. The velocity of the air was 1,500 feet per minute.

Results of sampling air for dust.

Time of sampling.	Dust in each cubic meter. *Mg.*
9 a. m. to 2.40 p. m	3.5
2.40 p. m. to 3.15 p. m	1.0
Blasting done at 3.15 p. m., smoke appeared at fan at 3.55 p. m.	
3.15 to 4.40 p. m	9.0
4.40 to 5.45 p. m	12.5
5.45 to 6.40 p. m	9.0
6.40 to 7.20 p. m	5.5
8.45 to 9.37 p. m	4.5

In different methods of drilling the amounts of dust produced were as follows:

Amounts of dust produced.

	Mg.
Dry drilling with piston type drills	68 to 201
Dry drilling with hammer drills	34 to 100
Drilling with water sprays in "hand stopes"	4.5
Drilling in "machine" stopes	3.8

a A micron equals 1/1000 of a millimeter, or about 1/25000 of an inch; the diameter of a red corpuscle is 8 microns.

The commission found by tests that respirators would not stop the fine dust, and as they did catch the coarse dust, allaying irritation of nose and throat, their effect was misleading.

The use of water is a great gain. In the Simmer Deep Mine, while drilling without sprays, in September, 1911, before blasting 80 to 280 milligrams of dust per cubic meter of upcast air were found; after blasting (fan stopped), 100 milligrams. With sprays in use, in September, 1912, the amount of dust before blasting was 0.2 to 3.3 milligrams per cubic meter; after blasting, 14 to 17.1 milligrams per cubic meter.

Belger fluid, chiefly calcium chloride with glue and water, was tried. It was found to have no advantage as a spray, but owing to the deliquescence of calcium chloride was thought to be advantageous for use in airways or passages in which the air was below saturation, to keep the surfaces moist and thus hold the dust.

As a result of the work of the several commissions mentioned above, drastic regulations were adopted in the South African mines, among which are the requirements in the mines regulations act (Transvaal) that—

No person shall in the drilling of holes use or cause or permit to be used any percussion machine drill unless a water jet or spray or other means equally efficient is provided and used so as to prevent the formation of dust by drilling, and unless the floor and sizes of the working place to a distance of at least 25 feet from the face be kept constantly wet.

No person shall in any part of the mine move any broken rock or ground or cause or allow the same to be moved if such rock or ground is in a dusty condition unless and until it and the floor, roof, and sides of the working place to a distance of at least 25 feet have been effectively wetted and kept wet so as to prevent the escape of dust into the air during removal.

The ganger shall in all development faces (except in the case of a winze being worked single shift) immediately after lighting up put into action the water blast which he shall have previously tested. If as a result of such test the water blast be found to be not in order no blasting shall take place.

The manager of a mine shall:

(*a*) Provide or cause to be provided an adequate and constant supply of water which is clear and odorless at every working place which is not naturally wet. Such supply shall be sufficient for effectively wetting the broken ground and for preventing formation of dust caused by drilling operations. Such water shall be supplied in metal pipes not less than 1 inch in diameter at a pressure of not less than 30 pounds to the square inch at each working place when all sprays and jets supplied from the same pipe are working. Such pipes shall reach to within 50 feet from the face and from there a sufficient length of hose shall be provided and used to bring water up to the face.

(*b*) Cause the surface in all working places, traveling ways, and shafts which are not naturally wet to be kept wet as far as practicable.

(*c*) As far as practicable cause such old stopes as tend to short-circuit or add dust to the ventilating current to be closed off and cause the ventilating current to be circulated along the working face.

(*d*) Provide in such shafts which are not wet ring sprays at suitable points to prevent dust being carried with the air current.

(*e*) Provide a water blast as near as practicable to all development faces (except winzes being worked on single shift.)

Among other improvements that have been introduced on the Rand are change houses, so that miners hoisted from the hot, humid atmosphere of the mines may have opportunity for bathing and for putting on dry clothing before going out into the cool, open air.

Owing to the hot atmosphere in the Transvaal mines, water used in wetting the mines tends to dry up rapidly, so that a few hours later clouds of dust may be raised by the concussion of blasting. Accordingly, either the development places should be resprayed or, as has been more recently proposed, continuous sprays may be used.

An alternative plan that has been tried [a] is the use of a mixture "consisting of a 50 per cent solution of molasses and water. * * * This mixture is sprayed on the roof and sides of development places, where it forms a slightly sticky coating. All dust settling on this surface is retained in a damp condition, thus preventing the usual cloud of dust raised by the concussion of blasting, whereas if water alone had been used the dust would have dried up after an interval of only a few hours, and been left to be disseminated at the next blast."

SILICOSIS IN THE QUARTZ MINES OF AUSTRALIA.

Statistics have shown that miners' phthisis is prevalent in the quartz mines of Bendigo, Australia. In a report on the health of miners there, Summons [b] gives the following figures regarding the annual deaths of miners from miners' phthisis, estimated as per 10,000 living at all ages: 1875–1879, 48.5 out of a total of 179.8; 1905–6, 129.6 out of a total of 270 deaths.

These figures show that since machine drills have been in use the number of men affected has increased enormously. Seemingly, the conditions are not so acute in the Bendigo mines as in those on the Rand, as the average number of years a miner worked in the Bendigo mines is 22.

In 1910 investigation was made into the prevalence of pulmonary disease among miners in western Australia. The report of the commissioner, Dr. J. H. L. Cumpston, does not bear out the conclusions previously held of the rarity of miners' phthisis.

---

[a] Gullachsen, B. C., The prevention of dust in underground workings: Jour. Chem. Met. and Min. Soc. of South Africa, January, 1914, p. 340.

[b] Summons, Walter, Report of an investigation at Bendigo into the prevalence, nature, causes, and prevention of miners' phthisis, 1907, p. 5.

PHTHISIS IN GERMANY.

Although Agricola, as cited in the beginning of this chapter, specifically refers to the presence of consumption in the Hartz mines, with which he was acquainted, the disease was probably due largely to poor ventilation, and as modern methods were adopted it is probable that with the better ventilation the health of the workers improved and they became less susceptible to the relatively small quantity of dust produced before the introduction of percussive machines. In recent years the Hartz mines have been practically exhausted, and extensive metal mining in Germany is confined largely to iron and zinc ores, in which the dust problem is not serious.

However, as to the effect of coal dust upon the lungs, two opposite opinions are held—one that the dust is not only harmless but even conducive to health, and the other that it is a danger to health. As pointed out in a German journal,[a] these discordant opinions are due to the fact that some are exposed to the inhalation of pure coal dust and others to the inhalation of shale dust with the coal dust, and frequently shale dust contains much free silica.

It has been found in Germany that industrial dusts have had a very serious influence. The Prussian statistics show that in 1909 persons suffering with tuberculosis had been admitted to the Prussian hospitals to the number of 82,576, which was 7.8 per cent of the total number of patients. In 1909 the total number of deaths in Prussia was 60,871, or 0.15 per cent of the population. The number of cases in Germany is between 800,000 and 1,300,000 in one year.

Sommerfeld [b] points out that of 1,000 persons 2.39 per cent died of pulmonary tuberculosis in occupations in which little dust is encountered (particularly agriculture); 5.64 per cent in work evolving organic dust; and 5.84 per cent in work producing metallic dust.

The disease was particularly manifest among workers of porcelain factories, where the rate was 14 per 1,000. Hirt[c] states that the average life of glass grinders is only 42½ years, and if they begin to work at 15 years of age they seldom live beyond the age of 30. The cause of such early death is the dangerous character of the dust produced in grinding, the dust being exceedingly fine and sharp. These data indicate that a fine sharp dust is an important factor in the causation of consumption.

PREVALENCE OF SILICOSIS AMONG MINERS OF THE UNITED STATES.

It has for many years been known to American engineers and operators that, in certain mining districts in the United States, as for

[a] S. B. B. Zeitung, 1911.
[b] Sommerfeld, Theodor, Handbuch der Gewerbekrankheiten, Berlin, 1898, p. 20.
[c] Hirt, Ludwig, Die Krankheiten der Arbeiter, Breslau, 1873, p. 245.

example in the quartz mines on the Mother Lode of California, and in the sheet-ground zinc mines of Joplin, Mo., there were most serious conditions, causing an excessive number of deaths of miners from pulmonary diseases. It was known that workers in metal mines in various parts of the country had been affected, but no comprehensive survey had been made, although the subject was alluded to from time to time in mining journals.

In the earlier mining and tunneling in the United States, as in other mining districts of the world, hand drilling with relatively small charges of explosive was used in breaking ground. With such conditions dust was a less serious problem. Formerly the number of miners engaged in quartz and other mines which had siliceous ores was small as compared with the number of miners engaged in mining coal, iron ore, and other ores with nonsiliceous gangue, and owing to the drifting of the miners from one point to another miners' consumption was not particularly noted. When, however, compressed-air percussive drills were introduced extensively into the quartz and siliceous rock mine, sminers' lung troubles became more common. This was intensified with the increasing depth of working with consequent rise in temperature of the mine air, making the men more susceptible to pulmonary troubles, which then came more conspicuously before the public.

In the past few years a new factor has become prominent in the mining problem in the quartz and schist mines—the development of new drills. There was a demand for a drill that would automatically throw a stream of water into the hole being drilled, thus preventing dust. As a result there was devised a water-injection drill which when properly used admirably serves the purpose of preventing dust from drilling operations. The disadvantage is that in drilling "uppers" the drill men are splashed with water, and where the air is cool they sometimes do not use the water, so that then, of course, the drilling operation makes dust. Nevertheless the introduction of this type of drill has been an important factor in lessening the production of dust in many mines.

Two other drills—the "stoper" and the "jack hammer"—recently come into use in the United States add to the difficulties. These drills are light and easily moved around, and their use has proved highly effective, the "stoper" for use in stopes, and the "jack hammer" for drilling block holes. Owing to the purposes for which the drills are used, internal water jets may be inconvenient for the jack-hammer type and not be attached.

The use of respirators has been proposed from the first. Self-contained oxygen breathing apparatus, although it would be effective, would be too cumbersome and expensive for regular use; and the miners will not use the ordinary respirator unless the conditions are

unusually bad. In fact, as pointed out by the British commissioners, Haldane and Martin, the protection afforded is very imperfect; the respirators leak around the edges, particularly after the filtering material has become wet from the moisture content of the expired air. Moreover, respirators are hot and uncomfortable, and as at the end of each respiration the open space is filled with expired air containing about 6 per cent of carbonic acid, increased depth of respiration is necessary. Men who are wearing respirators can not freely communicate with one another. Consequently in many districts it is difficult to get the men to use the respirators. The recent South African commission found that the respirators it tested were ineffective.

Various methods of lessening rock-drill dust have been tried, such as surrounding the mouth of the drill hole with a bag through which the drill passes; although the arrangement is effective when properly placed, it is rather difficult to adjust and keep in place, and when offered to the miners they in general will not use it. Such devices were also considered ineffective by the South African commission, and the final remedy adopted was the general use of water.

The United States Bureau of Mines immediately after its establishment, made a rough preliminary inquiry into the question. Subsequently, in May, 1911, the Bureau of Mines and the Public Health Service were jointly requested by the secretary of the national association for the study and prevention of tuberculosis to investigate the subject in accordance with the following resolutions adopted by the board of directors of that association:

Whereas the royal commission appointed by the governor general of Australia to inquire into the subject of miners' lung diseases has ascertained a truly alarming state of affairs, resulting from the extensive use of rock drills underground, not provided with spraying apparatus to diminish the production of health-injurious dust; and

Whereas a large proportion of our mining population are exposed to conditions quite similar to those reported upon adversely in the Australian Commonwealth; and

Whereas the actual extent of the occurrence of lung diseases among metal miners in the United States is at present unknown:

Resolved by the board of directors of the national association for the study and prevention of tuberculosis, That we recommend to the President and the Congress of the United States that a thorough investigation into the whole subject of the sanitary conditions surrounding metal mining under ground, with special reference to diseases of the lungs, be made by the United States Bureau of Mines, the Public Health and Marine Hospital Service, and the appropriate State authorities.

Prior to this the Public Health Service and Bureau of Mines had cooperated in some investigations as to the prevalence of contagious and infectious diseases among miners; and it was then decided to make a specific investigation of the prevalence of miners' lung diseases in metal mines. Accordingly, Passed Asst. Surg. S. C. Hotchkiss began a survey of metal mines in various places, and found considerable silicosis in certain kinds of mines. However, the investiga-

tion had hardly been started when Dr. Hotchkiss's sudden and untimely death led to the loss of the data collected. Subsequently it was decided by the Director of the Bureau of Mines to make a detailed investigation of the prevalence of pulmonary diseases in the Joplin district of Missouri, for the special purpose of obtaining the life history of the miners, that district being selected because the great majority of the miners are American born, and have worked almost exclusively there. At the request of the Director of the Bureau of Mines the Surgeon General of the Public Health Service detailed Dr. A. J. Lanza, passed assistant surgeon, to cooperate with Edwin Higgins, mining engineer of the bureau, to make a survey of the district, especially of the sheet-ground mines, in which flint dust was believed to be the largest source of trouble in the large number of fatalities from lung diseases in the Joplin district. The soft-ground mines of the district are for the most part in limestone and clay formation and it was not expected that siliceous dust would be found in dangerous quantities, a supposition that was confirmed by the subsequent investigations with which this report deals.

Before the inquiry was finished, owing to the serious conditions found, it was deemed important to publish a preliminary report, and this appeared as Bureau of Mines Technical Paper 105.[a] The investigators, Messrs. Lanza and Higgins, were accorded splendid cooperation by the Missouri State mine inspectors, by the mine operators of the district, and by the miners, and reforms were immediately begun. Statistics gathered in the immediate future may not show great improvements, owing to the fact that many persons were already seriously affected. Ultimately, however, there is likely to be a great change for the better.

Simultaneously with carrying on the field work an investigation was conducted as to the character of the dust produced in the mines, which in turn led back to a study of the origin of chert deposits in which the zinc and lead of the sheet ground is found. The study of the samples of chert was conducted by F. B. Laney, geologist of the United States Geological Survey, whose report is presented herewith.

---

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines; a preliminary report: Tech. Paper 105, Bureau of Mines, 1915, 48 pp.

THE CHERT OR FLINT OF THE JOPLIN DISTRICT.

By F. B. Laney.

INTRODUCTION.

In the hard-ground or sheet-ground mines of the Joplin district, the principal rock associated with the ores is locally known as flint. It is dense, extremely hard, gray or black, and consists almost wholly of silica. Variations in color are largely due to carbonaceous matter and small amounts of iron oxide. According to modern usage, this rock may properly be called chert, the term used by the United States Geological Survey, and it is so designated in this report.

On the basis of color and texture there are in the Joplin district two distinct types of chert. One is light to bluish gray, exceedingly dense and fine grained, and very brittle; the other is very dark or black, of much coarser texture, and slightly less brittle. In point of age and conditions of deposition or formation, there are believed to be three distinct types, as follows: An original light to bluish gray chert, probably contemporaneous in deposition with the limestone in which it occurs in beds of varying thickness; a younger, secondary chert similar in color and texture, but occurring as a replacement of the limestone and in fractures in the original chert; and, finally, the secondary black chert or jasperoid. In other words, it is believed that the light to bluish gray chert is of two periods of deposition or formation and is the result of two separate and distinct processes, and the black chert or jasperoid is of one extended period of deposition and the result of one type of process. The gray chert is older than the ores, and although its surface may be coated with the ores of zinc and lead and they may fill fractures in it, they are never found disseminated throughout the mass of the rock. On the other hand, the black chert or jasperoid occurs as fracture filling in the older chert, and makes up the matrix for large masses of breccia, the fragments of which consist of sharply angular pieces of the older chert. The ore minerals are also widely disseminated throughout the body of the black chert. It is therefore clear that the jasperoid is younger than the gray chert and probably contemporaneous with the deposition of the ores.

Both types of the rock break with sharp conchoidal fracture into numerous splinters and particles with exceedingly sharp points and edges that cut almost like razors. This mode of fracture is more pronounced in the dense, older chert than in the jasperoid. Different observers have noted that when either type of the chert, but more especially the older, is broken the fracture faces are so curved that

the fragments can not be made to fit together perfectly, thus indicating that the rock is under an internal stress or strain. This fact, to a certain degree, may account for the brittleness of the rock and its tendency to break into minute sharp-edged fragments.

Chert, including jasperoid, forms by far the most important gangue material in the Joplin ore deposits. No mines are entirely free from it, and in some it is practically the only rock intimately associated with the ores. An idea of the enormous quantities of chert that have to be broken, hoisted, and crushed in mining and milling the ores may be gained by a glance at the thousands and thousands of tons of tailings and "chats," both of which consist almost wholly of chert.

All writers on the Joplin district have necessarily devoted much space to the chert, and hence the literature on the subject is considerable. All writers agree fairly well in classifying the material into three divisions or generations—an older, fossiliferous chert; a still older, nonfossiliferous, gray chert; and a younger, black variety. Buckley and Buehler [a] make the following statement on the subject:

> There are at least three generations of flint associated with the limestone and the ore bodies. The first is a white variety, which is thought to be original, since it does not contain fossils common to the limestone. The second is a white, gray, or blue variety containing fossils and thought to be a replacement of the limestone. The third is a black flint, which evidently resulted from either the silicification of arenaceous mud or the precipitation of silica from underground waters, perhaps both. This flint contains no fossils and serves as a matrix, in which are embedded fragments of the white flint, forming what is commonly known as a breccia. In places both the white and the black flints have been decomposed. When decomposed, the white flint is known to the miners as "cotton rock," on account of its white, soft character, while the decomposed black flint is called "cod rock."

For the purposes of this report it is not considered necessary to discuss separately the two classes of older chert, which are much alike so far as their relation to the ores is concerned. The jasperoid is so different from the other chert and is so much more intimately associated with the ores that it merits separate consideration.

GRAY CHERT.

GENERAL CHARACTERISTICS.

The older, gray or bluish-gray chert is closely associated with the ores, both as beds of varying thickness—a few inches to several feet—of irregular lateral extent and as ellipsoidal nodules usually less than 6 inches in diameter. Many of the beds or sheets of chert have a wavy or irregular surface, and in a few the lamination planes of the limestone extend into and through the nodules. The rock varies much in color, owing to impurities, iron staining, and different degrees of weathering or decomposition. The weathered material

[a] Buckley, E. R., and Buehler, H. A., The geology of the Granby area: Missouri Bureau of Geology and Mines, vol. 4, 2d ser., 1906, pp. 30-31.

has a flat-white and chalky appearance, except for iron stains of varying shades of yellow, and is so soft that it can be cut readily with a knife. Much of the chert, especially that in heavy beds, is shattered or broken into small, sharply angular fragments, which in many localities are cemented by the younger, black chert or jasperoid into beautiful breccias. The rock when fresh is very hard and brittle and breaks readily with nearly perfect conchoidal fracture into fragments of varying shapes and sizes, all with sharp points and razorlike edges. In fact, perhaps the most characteristic feature of the fresh rock is its tendency to break into sharp-edged fragments.

Much of the chert shows small vugs or openings; some of these are lined with minute, well-terminated quartz crystals. Some of these openings contain blende and other ore minerals in more or less well-developed crystals, but the sulphides are rarely or never disseminated through the mass of the rock. Much of the rock also contains fractures, many of which have been more or less perfectly healed either by the deposition of younger, gray chert, often in the form of minute, anhedral quartz grains, or by the deposition of jasperoid. The rock is invariably so dense and so fine grained that little or nothing of its texture or mineralogical composition can be determined by the unaided eye, or even by a hand lens. Much of it is highly fossiliferous, the fossils almost invariably being those that originally had calcareous shells, or supports, such as corals, brachiopods, crinoids, or bryozoa. In some of the chert the fossils are only partly silicified, and in places the chert grades, by decrease of silica and corresponding increase of calcite, into nearly pure limestone, thus showing its origin. This subject is treated in greater detail in the discussion of the origin of the chert.

CHARACTERISTICS AS SHOWN BY THE MICROSCOPE.

In thin section, under the microscope, the gray chert is seen to be composed largely of exceedingly fine-grained irregularly interlocking quartz, the grains of which vary from 0.05 mm. to a size so small that the microscope all but fails to resolve them; in fact, most of this chert is typically cryptocrystalline. Although the texture is always very fine and dense there is considerable variation, as is well shown in Plates XV, *A*, XV, *B*, and XVI, *A*, which are reproductions of photomicrographs of typical gray chert.

The microscope shows that in much of the chert a great deal of the silica is present as chalcedony. In one thin section studied, the proportion of chalcedony was at least 30 per cent; but the amount varies greatly, and in some specimens examined chalcedony, if present, could not be identified. This peculiarity of the Joplin cherts was noted and described long ago by Hovey.[a] The chalcedony is usually

[a] Hovey, E. O., Lead and zinc deposits of Missouri: Missouri Geol. Survey, vol. 7, 1894, p. 728.

slightly yellowish, probably owing to varying but small amounts of hydrated ferric oxide. It is transparent or slightly translucent in ordinary light, but between crossed nicols it shows beautifully the typical black cross or aggregate polarization. Its relation to the cryptocrystalline quartz so characteristic of these rocks indicates pretty clearly that the quartz has largely resulted from the crystallization or devitrification of the chalcedony, and that at one period in its history the chert was largely, if not wholly, in the colloidal or chalcedonic condition.

Another interesting feature of the gray chert is that in many samples the grains of quartz show undulatory extinction, indicating that the rock is under stress or strain. There is no indication that the Joplin region has ever been subjected to such intense dynamic metamorphism as would be necessary to develop these "strain shadows" in the quartz. It is believed, therefore, that the phenomenon is due to internal stresses, probably resulting from the change from colloidal to crystalline condition. This internal stress probably has an important effect on the tendency of the rock to break so readily into sharp fragments.

Much of the rock is fossiliferous and the fossils, as has been stated, are largely those that originally were calcareous. They show all degrees of silicification, from pure limestone to pure chert. Such silicifications are almost invariably much more coarsely crystalline than the matrix in which they are embedded. The microscope also reveals what appears to be the remains of sponge spicules. Most of these consist of small spindle-shaped areas more coarsely crystalline than the rest of the rock. Some, however, are trident-shaped, as is shown in Plate XVI, *A*. The presence of the remains of sponge spicules is important as indicating the origin of the chert and will be considered in some detail in the discussion of that subject.

ANALYSES OF SAMPLES OF GRAY CHERT.

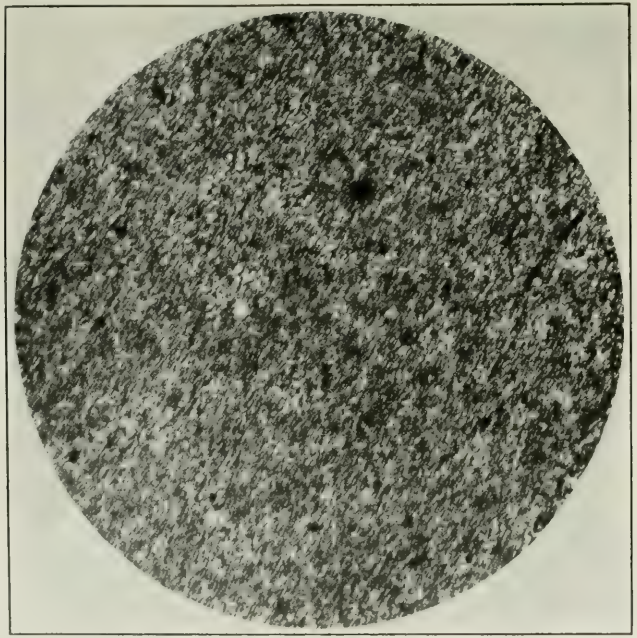
The results of chemical analyses of samples of gray chert follow.

Results of chemical analyses of the gray chert of the Joplin district.[a]

[E. A. Schneider, analyst.]

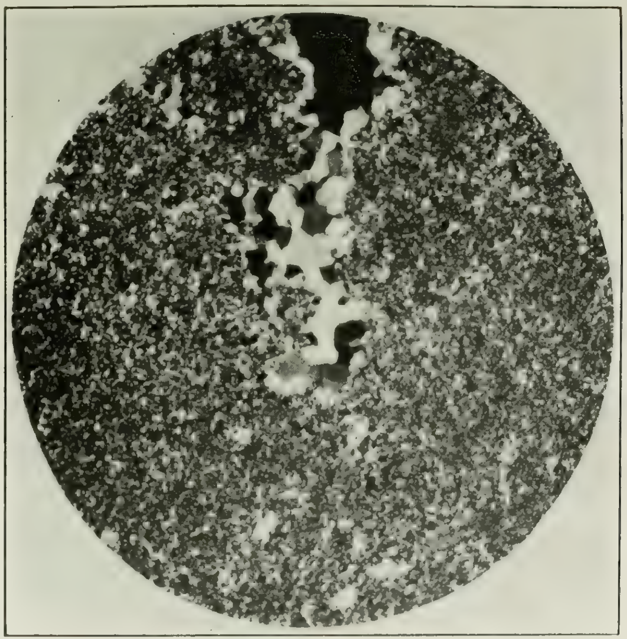
Constituent.	Percentage in sample—						
	A	B	C	D	E	F	G
SiO_2	98.17	98.92	98.71	99.46	99.23	98.60	99.13
Al_2O_3 and Fe_2O_3	.83	.48	.43	.29	.22	.52	.16
MgO	.01	.02	Trace.	Trace.	Trace.	.01	.24
CaO	.05	.03	.03	.04	.02	.10	Trace.
Loss on ignition	.78	.42	.50	.34	.50	.40	.20
	92.84	99.87	99.69	100.13	99.97	99.62	99.50

[a] Clarke, F. W., Analyses of rocks and minerals from the laboratory of the United States Geological Survey, 1880–1908: U. S. Geol. Survey Bull. 419, 1910, p. 186.



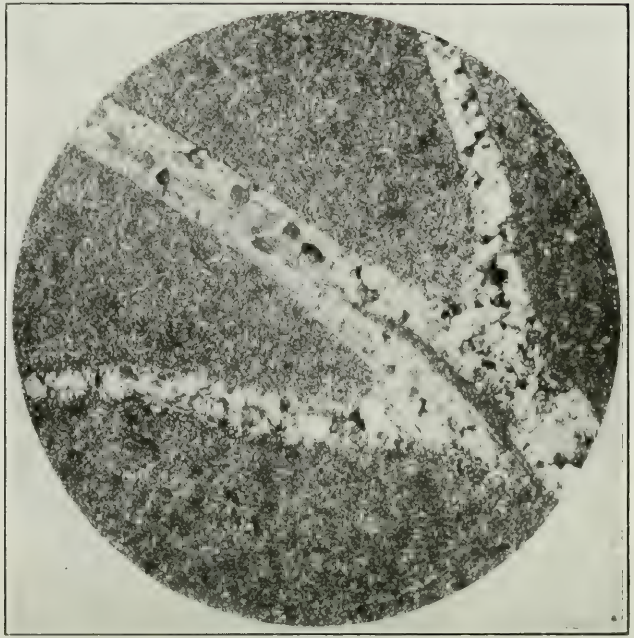
1 mm.

A. PHOTOMICROGRAPH, CROSSED NICOLS, OF THIN SECTION OF DENSE GRAY CHERT. TEXTURE IS TYPICALLY CRYSTALLINE, AND MUCH OF THE ROCK IS SO FINE GRAINED THAT THE MICROSCOPE FAILS TO RESOLVE IT.



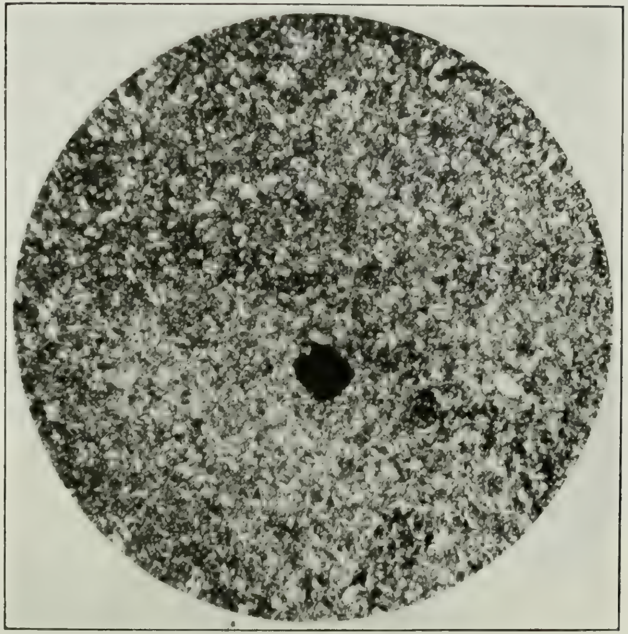
1 mm.

B. PHOTOMICROGRAPH, CROSSED NICOLS, OF THIN SECTION OF THE COARSER GRAY CHERT. GRAINS ARE MUCH LARGER AT BORDERS OF SMALL OPENING OR VUG, IN UPPER PART OF SECTION, THAN ELSEWHERE.



1 mm.

A. PHOTOMICROGRAPH, CROSSED NICOLS, OF THIN SECTION OF FINE-GRAINED OLDER GRAY CHERT, SHOWING REMAINS OF TRIDENT-SHAPED SPONGE SPICULE.



1 mm.

B. PHOTOMICROGRAPH, CROSSED NICOLS, OF THIN SECTION OF JASPEROID. TEXTURE SHOWN, THOUGH CONSIDERABLY COARSER THAN THAT OF THE AVERAGE GRAY CHERT, IS FINER THAN MUCH OF THE JASPEROID.

The samples were collected in the Joplin district by W. P. Jenney, and represent localities as follows:

Sample A.—Unaltered chert, East Hollow, Belleville, Mo.
Sample B.—Partly altered chert, from the same locality as sample A.
Sample C.—Altered to "cotton rock," from the same locality as sample A.
Sample D.—Surprise mine, Joplin, Mo.
Sample E.—Blue chert, unaltered, Bonanza shaft, Galena, Kans.
Sample F.—From the same locality as sample E.
Sample G.—Altered chert, from the same locality as sample E.

These analyses of representative specimens of the gray chert show clearly that, whatever the origin and physical condition of the chert, it is at present made up almost wholly of silica. The small loss on ignition also indicates that by far the greater part of the silica is in the form of quartz. Field observations by the writer in many places in the Joplin district and in other localities in Missouri afforded conclusive evidence that much of this rock represents a replacement of the limestone by silica. The analyses, supplementing as they do the microscopic examinations, show how completely parts of the limestone may be silicified.

The analyses, when compared with those of the younger black chert or jasperoid, show 3 to 5 per cent higher silica content, less iron and alumina, and less loss upon ignition, as well as no carbonaceous matter.

ORIGIN OF GRAY CHERT.

It may not be out of place to make a few statements in regard to the probable origin and manner of deposition of the chert. As has been stated, it is believed that the gray chert is of two periods of deposition or formation, one contemporaneous with and one later than the deposition of the limestone in which it occurs. Some of the heavy beds of chert are continuous over wide areas and occur at definite horizons in the limestone. These are believed to have been deposited contemporaneously with the limestone and to have been formed from siliceous material deposited with the limestone.

Another part of the chert is clearly a replacement of the limestone in which it occurs. Limestone and chert are found in every gradation from pure limestone to pure chert. It is also well established that the alteration of limestone into chert has taken place on a large scale in many places in the Mississippi Valley, and as a result great masses of limestone have been replaced by chert.

Much of the nodular chert is also believed to be a replacement of limestone and consequently of secondary deposition. There are no means of determining how much of the chert is of primary nor how much is of secondary deposition, but it is believed that a large percentage of the total is of secondary origin and represents a replacement of the limestone.

The ultimate origin of a large part of the original chert is believed to have been siliceous materials, such as tests, shells, and spicules of sponges, which were deposited contemporaneously with the calcareous material that formed the limestone. That at least a part of the chert is of organic origin is conclusively shown by the fragments of sponge spicules frequently found in much of the chert. Although it is believed that much of the chert is of organic origin, the writer recognizes the possibility that a part, possibly the greater part, may represent chemically precipitated silica derived from clay and other silicates in solution in the sea water during the deposition of the limestone. Probably, both processes were active, but there are no means of ascertaining which was the more important. The form and texture of the cherts indicate that, whatever the source of the silica, a large part of it was probably precipitated in the colloidal condition. Perhaps the masses of siliceous tests and shells formed centers around which the dissolved silica collected, there being at the same time more or less solution of the tests and shells themselves.

The secondary gray chert, although in composition, texture, and general appearance closely similar to the original gray chert, is much younger and was deposited under entirely different conditions. That it is a replacement of the limestones and dolomites by silica is clearly shown by the fact that the calcareous rock is found in every stage of replacement from pure dolomite or limestone to pure gray chert. Moreover, the chert contains an abundance of originally calcareous fossils such as crinoids, brachiopods, and corals, that are now entirely silicified. Similar replacement of limestones and dolomites by chert is common throughout the whole Mississippi valley, whole beds of calcareous rock having been completely replaced by chert.[a] Much of the nodular chert is also known to be secondary, and such nodules, so far as the writer is aware, can in no way be distinguished from the nodules of the original and older chert. There are, therefore, no satisfactory means of determining definitely what proportion of the Joplin cherts represents replacement of calcareous rocks and what is of original deposition and therefore contemporaneous with the limestone.

The source of the silica of the secondary chert may have been any siliceous rock exposed to the action of solvent waters. Much of it has been dissolved, carried, and deposited by the ground water, which in this region always carries in solution an appreciable amount of silica. The conditions determining silicification are not known, but they assuredly are varied. Much silicification has taken place at considerable depths underground and seems to be in no way con-

[a] Ball, S. H., and Smith, A. F., The geology of Miller County: Missouri Bureau of Geology and Mines, vol. 1, 2d ser., 1903, pp. 145-147.

nected with the agencies of weathering. On the other hand, as shown by Bain and Ulrich,[a] much of the chert "as it now occurs is largely the segregation of siliceous matter under conditions of slow subaereal decomposition of the limestone." As regards the Joplin district, this last mode of formation, although applicable to the chert in natural outcrops or near surface, is certainly not applicable to that associated with the ores. As these theories of the origin of the chert involve processes that are still active, it is altogether probable that replacement is going on and that the calcareous rock is now being altered to chert.

JASPEROID OR BLACK CHERT.

GENERAL CHARACTERISTICS.

Aside from the carbonate rocks, the most prominent gangue material in the so-called "sheet ground" and much of the "open ground" is a dense, fine-grained, dark colored or black, hard, siliceous rock which closely resembles chert. This material has been designated by various names, such as ozarkite, cherokite, secondary chert, and jasperoid. The term jasperoid was first applied in 1907 by Smith and Siebenthal[b] in their folio on the Joplin district, and is at present the name used by the United States Geological Survey.

Jasperoid occurs extensively in all the sheet-ground deposits, in which it usually forms the matrix for more or less of the ore. It also serves as a matrix for much of the chert breccia in all types of mines, and in many places layers of it are intercalated in the dense older gray chert. Occasionally it shows a decided rhythmic banding due to concentration of certain of its constituents in narrow alternating bands. The greater part of the jasperoid, however, is dense, fine-grained, fairly uniform, and black, without indications of banding. The rock, although somewhat coarser in texture than the older gray chert, presents practically all the physical properties of true chert, being hard and brittle and breaking with pronounced conchoidal fracture into knife-edged and sharp-pointed fragments, although possibly not quite as readily as the true chert. These are the characteristics that make the dust from the rock so injurious to the lungs of miners.

CHARACTERISTICS AS SEEN BY THE MICROSCOPE.

In thin section under the microscope the purest or most highly siliceous phases of the jasperoid are seen to be composed of a very

[a] Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri: U. S. Geol. Survey Bull. 267, 1905, pp. 27-30.

[b] Smith, W. S. T., and Siebenthal, C. E. Geol. Atlas U. S., Joplin district folio (No. 148): U. S. Geol. Survey, 1907, p. 14.

fine grained groundmass of approximately equidimensional interlocking grains of quartz that vary in size from 0.02 mm. in diameter down to sizes that the microscope fails to resolve. Irregularly distributed throughout this groundmass are numerous larger elongated and roughly rectangular grains of quartz that vary much in size, being 0.03 to 0.08 mm. in longest direction, which is usually two to three times that of the shortest grains, so that the texture of the chert roughly suggests the so-called ophitic texture of certain igneous rocks. Except a few small specks or grains of dolomite or limestone and particles of sphalerite and pyrite, the only other feature revealed by the microscope is the presence of innumerable minute black, opaque particles which chemical tests show to be carbonaceous matter. This is rather evenly distributed throughout the rock and accounts for its dark color. Although there is much exceedingly fine-grained material in the jasperoid, the rock as a whole has a decidedly coarser texture than the older gray chert. The microscope also corroborates the macroscopic evidence that in many, if not most, instances the jasperoid is a replacement of the limestone or dolomite. Specimens showing almost every step from calcareous rock to jasperoid are easily obtainable. Much of the jasperoid contains, in addition to the ragged sphalerite grains, numerous rhombohedral crystals of dolomite. Smith and Siebenthal[a] say:

At numerous places dolomite occurs in the jasperoid in rhombohedrons, usually with clear-cut crystal boundaries. Many of these contain as inclusions, minute crystals of quartz and rarely sphalerite is found as a rule in well-defined crystals. Sphalerite occurring as one of the constituents of jasperoid usually presents a smooth outline where adjacent to dolomite, but where bordered by quartz its boundaries, even where it shows general crystal outlines, almost invariably yield to those of the quartz so as to produce minute irregularities at least.

The general appearance of the section of the finer-grained jasperoid as seen under the polarizing microscope is shown in Plate XVI, *B* (p. 103). The thin section from which this photomicrograph was made was from the fine-textured phase of the rock, and shows much finer grain than is found in the average jasperoid.

ANALYSES OF JASPEROID.

The following chemical analyses of jasperoid were made in the laboratory of the Geological Survey and show the composition of the purer phases of the rock.

---

[a] Smith, W. S. T., and Siebenthal, C. E., Geol. Atlas U. S., Joplin district folio (No. 148), U. S. Geol. Survey, 1907, p. 14.

Results of analyses of jasperoid from the Joplin district, Mo.[a]

Constituent.	Percentage in sample—			
	A[b]	B[c]	C[c]	D
SiO_2	95.26	95.77	97.33	94.72
Al_2O_3	.57	1.84	1.89	4.00
Fe_2O_3	None.			
FeO	.69			
MnO	None.			
MgO	.05	.24	.09	Trace.
CaO	.25	.54	.11	1.18
Water		1.17	.77	
Organic matter	Large.			

[a] Bain, H. F., Van Hise, C. R., and Adams, C. I., Lead and zinc deposits of the Ozark region: Twenty-second Annual Rept., U. S. Geol. Survey, pt. 2, 1902, p. 121.

[b] George Steiger, analyst.

[c] L. G. Eakins, analyst. See Clarke, F. W., Analyses of rocks from the laboratory of the United States Geological Survey, 1880-1903: U. S. Geol. Survey Bull. 228, 1904, p. 297.

If, as is believed by Smith and Siebenthal,[a] the black chert represents a part of the limestone that was replaced by silica and other material when the ores were deposited, the analyses show that the replacement has been all but complete. Field observations and microscopic study of much black chert, as well as the analyses themselves, indicate that the material chosen for chemical study was pure jasperoid. Material ranging from almost unaltered limestone to typical black chert is abundantly available in the district.

Comparison of these analyses of the black chert with those of the older gray chert shows that the two types of rock differ mainly in the silica content, the older chert containing 3 to 5 per cent more silica than the black rock. The black chert, on the other hand, contains appreciably more iron, alumina, lime, and organic matter than does the older gray chert.

ORIGIN OF JASPEROID.

The investigations herein recorded throw some light on the origin of the jasperoid and led the writer to agree with the hypothesis offered by Smith and Siebenthal,[a] whose conclusions are as follows:

> It [the jasperoid] occurs locally in lenticular forms such as characterize the occurrence of limestone in chert, and the manner of its occurrence in the sheet ground suggests the replacement of sheets and lenses of limestone. More definite evidence is found in the fact that all stages of the process of change from unaltered limestone to jasperoid have been observed, both megascopically and microscopically. Corroborative facts are the occurrence here and there of fossils, particularly crinoid stems, in typical jasperoid as well as the presence of stylolites in a somewhat calcareous jasperoid at the Jack Johnson mine near Chitwood.

[a] Smith, W. S. T., and Siebenthal, C. E., Geol. Atlas U. S., Joplin district folio (No. 148), U. S. Geol. Survey. 1907, p. 14.

The general process of replacement, as shown by the microscope, is as follows: First, a few scattered crystals of quartz appear in the limestone; with increase in the proportion of quartz the limestone decreases until in its later stages the rock consists chiefly of a granular aggregate of quartz, with scattered, ragged grains of calcite, mere remnants of the former limestone. Finally, even these disappear.

This explanation of the origin of jasperoid accounts for the scarcity of limestone in the ore deposits. In the sheet ground, limestone is rarely found, jasperoid occupying those positions in which limestone would normally be looked for. In the breccia, limestone blocks are sometimes found, but the chert breccia of many mines appears to be wholly free from limestone, although dolomite and chert may border it on one side and limestone with chert on the other. The replacement of limestone by jasperoid would not only account for the apparent absence of much or most of the limestone to be expected in the chert breccias, especially in those mines which are practically free from dolomite, as the Oronogo mines and those in the hard sheet ground, but would also explain the fractured beds of chert sometimes seen suspended in a matrix of jasperoid.

Most of the geologists who have studied the Joplin ore deposits believe that the silica forming the jasperoid was deposited originally in colloidal form. The first writer to suggest that it was deposited as colloidal silica and later changed to the crystalline condition is Bain,[a] who studied the district in 1900. The premises on which he bases his hypothesis were stated by him substantially, as follows: Crystals of sphalerite completely inclosed in jasperoid possess well-defined crystal outlines with no indication that they were deposited in cavities; and the microscope does not reveal any such concentric laminations in the matrix immediately surrounding the crystals as commonly surround crystals that have in their growth crowded aside the matrix.

In 1915 Siebenthal,[b] after an extended study of the ore deposits of the district, reviewed the work of Bain and concurred with him in his conclusions in regard to the original colloidal conditions of the silica of the jasperoid. The writer believes not only that the silica of the jasperoid was deposited in the colloidal condition but also that the silica of the older chert was to a large extent similarly deposited. Of course the deposition took place long before the period of mineralization and the development of the jasperoid.

---

[a] Bain, H. F., Van Hise, C. R., and Adams, C. I., work quoted, pp. 106, 108.

[b] Siebenthal, C. E., The origin of the zinc and lead deposits of the Joplin region: U. S. Geol. Survey Bull. 606, 1915, pp. 181–183.

PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF METAL MINING.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

Limited editions of the following Bureau of Mines publications are temporarily available for free distribution. Requests for all publications can not be granted, and applicants should select only those publications that are of especial interest to them. All requests for publications should be addressed to the Director, Bureau of Mines, Washington, D. C.

Bulletin 62. National mine-rescue and first-aid conference, Pittsburgh, Pa., September 23–26, 1912, by H. M. Wilson. 1913. 74 pp.

Bulletin 75. Rules and regulations for metal mines, by W. R. Ingalls, James Douglas, J. R. Finlay, J. Parke Channing, and John Hays Hammond. 1915. 296 pp., 1 fig.

Bulletin 80. A primer on explosives for metal miners and quarrymen, by C. E. Munroe and Clarence Hall. 1915. 125 pp., 15 pls., 17 figs.

Bulletin 101. Abstracts of current decisions on mines and mining, October, 1914, to April, 1915, by J. W. Thompson. 1915. 138 pp.

Bulletin 113. Abstracts of current decisions on mines and mining, reported from May to September, 1915, by J. W. Thompson. 1916. 124 pp.

Bulletin 118. Abstracts of current decisions on mines and mining, October to December, 1915, by J. W. Thompson. 1916.

Bulletin 126. Abstracts of current decisions on mines and mining, January to April, 1916, by J. W. Thompson. 1916.

Technical Paper 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

Technical Paper 6. The rate of burning of fuse as influenced by temperature and pressure, by W. O. Snelling and W. C. Cope. 1912. 28 pp.

Technical Paper 7. Investigations of fuse and miners' squibs, by Clarence Hall and S. P. Howell. 1912. 19 pp.

Technical Paper 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

Technical Paper 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

Technical Paper 15. An electrolytic method of preventing corrosion of iron and steel, by J. K. Clement and L. V. Walker. 1913. 19 pp., 10 figs.

Technical Paper 18. Magazines and thaw houses for explosives, by Clarence Hall and S. P. Howell. 1912. 34 pp., 1 pl., 5 figs.

Technical Paper 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

Technical Paper 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

Technical Paper 30. Mine accident prevention at Lake Superior iron mines, by D. E. Woodbridge. 1913. 38 pp., 9 figs.

Technical Paper 46. Quarry accidents in the United States during the calendar year 1911, compiled by A. H. Fay. 1913. 32 pp.

Technical Paper 58. The action of acid mine water on the insulation of electric conductors; a preliminary report, by H. H. Clark and L. C. Ilsley. 1913. 26 pp., 1 fig.

Technical Paper 59. Fires in Lake Superior iron mines, by Edwin Higgins. 1913. 34 pp., 2 pls.

Technical Paper 61. Metal-mine accidents in the United States during the calendar year 1912, compiled by A. H. Fay. 1913. 76 pp., 1 fig.

Technical Paper 62. Relative effects of carbon monoxide on small animals, by G. A. Burrell, F. M. Seibert, and I. W. Robertson. 1914. 23 pp.

Technical Paper 67. Mine signboards, by Edwin Higgins and Edward Steidle. 1913. 15 pp., 1 pl., 4 figs.

Technical Paper 92. Quarry accidents in the United States during the calendar year 1913, compiled by A. H. Fay. 1914. 76 pp.

Technical Paper 105. Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines; a preliminary report, by A. J. Lanza and Edwin Higgins. 1915. 48 pp., 5 pls., 4 figs.

Technical Paper 116. Miners' wash and change houses, by J. H. White. 1915. 27 pp., 3 pls., 3 figs.

Technical Paper 129. Metal-mine accidents in the United States during the calendar year 1914, compiled by A. H. Fay. 1916. 96 pp., 1 pl., 3 figs.

Miners' Circular 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

Miners' Circular 10. Mine fires and how to fight them, by J. W. Paul. 1912 14 pp.

Miners' Circular 13. Safety in tunneling, by D. W. Brunton and J. A. Davis. 1913. 19 pp.

Miners' Circular 17. Accidents from falls of rock or ore, by Edwin Higgins. 1914. 15 pp., 8 figs.

Miners' Circular 20. How a miner can avoid some dangerous diseases, by A. J. Lanza and J. H. White. 1916. 26 pp., 4 figs.

PUBLICATIONS THAT MAY BE OBTAINDE ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

The editions for free distribution of the following Bureau of Mines publications are exhausted, but copies may be obtained by purchase from the Superintendent of Documents, Government Printing Office, Washington, D. C., or can be consulted at public libraries. Prepayment of the price is required and should be made in cash (exact amount) or by postal or express money order payable to the Superintendent of Documents.

The Superintendent of Documents is an official of the Government Printing Office and is not connected with the Bureau of Mines.

Bulletin 61. Abstract of current decisions on mines and mining, by J. W. Thompson. 1913. 82 pp. 10 cents.

Bulletin 79. Abstracts of current decisions on mines and mining, March to December, 1913, by J. W. Thompson. 1914. 140 pp. 20 cents.

Technical Paper 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

Technical Paper 24. Mine fires, a preliminary study, by G. S. Rice. 1912. 51 pp., 1 fig. 5 cents.

Technical Paper 29. Training with mine-rescue breathing apparatus, by J. W. Paul. 1912. 16 pp. 5 cents.

Technical Paper 40. Metal-mine accidents in the United States during the calendar year 1911, compiled by A. H. Fay. 1913. 54 pp. 5 cents.

Technical Paper 41. The mining and treatment of lead and zinc ores in the Joplin district, Mo., a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs. 5 cents.

Technical Paper 47. Portable electric mine lamps, by H. H. Clark. 1913. 13 pp. 5 cents.

Technical Paper 73. Quarry accidents in the United States during the calendar year 1912, compiled by A. H. Fay. 1914. 45 pp. 5 cents.

Technical Paper 77. Report of the Committee on Resuscitation from Mine Gases, by W. B. Cannon, G. W. Crile, Joseph Erlanger, Yandell Henderson, and S. J. Meltzer. 1914. 36 pp., 4 figs. 5 cents.

Technical Paper 94. Metal-mine accidents in the United States during the calendar year 1913, compiled by A. H. Fay. 1914. 73 pp. 10 cents.

Miners' Circular 8. First-aid instructions for miners, by M. W. Glasgow, W. A. Raudenbush, and C. O. Roberts. 1913. 67 pp., 51 figs. 10 cents.

Miners' Circular 15. Rules for mine-rescue and first-aid field contests, by J. W. Paul. 1913. 12 pp. 5 cents.

INDEX.